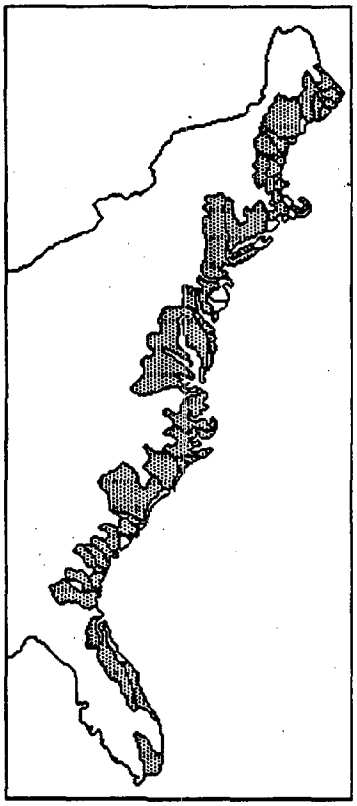
National Estuarine Inventory

The Quality of Shellfish Growing Waters on the East Coast of the United States

Dorothy L. Leonard, Marlene A. Broutman
and Kristen E. Harkness

March 1989



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

NOAA's National Estuarine Inventory

The National Estuarine Inventory (NEI) is a series of related activities of the Office of Oceanography and Marine Assessment (OMA), National Oceanic and Atmospheric Administration (NOAA) to develop a national estuarine data base and assessment capability. The NEI was initiated in June 1983 as part of NOAA's program of strategic assessments of the Nation's coastal and oceanic resources. No comprehensive inventory or data base for the Nation's estuaries could be found prior to the NEI in spite of the high value, intense use, frequent overuse, and thousands of scientific studies related to various aspects of estuaries. Without this fundamental set of information developed for the NEI, it is impossible to analyze or compare the estuaries that make up the Nation's estuarine resource base.

The cornerstone of the NEI is the National Estuarine Inventory Data Atlas. Volume 1, completed in November 1985, identifies 92 of the most important estuaries and subestuaries of the contiguous USA; presents information through maps and tables on physical and hydrologic characteristics of each estuary; and specifies a commonly derived spatial unit for all estuaries, the estuarine drainage area (EDA), for which data are compiled. These estuaries represent approximately 90 percent of the estuarine water surface area and 90 percent of the freshwater inflow to estuaries of the East Coast, West Coast, and Gulf of Mexico. Volume 2 presents area estimates for seven categories and 24 subcategories of land use as well as 1970 and 1980 population estimates. Land use data are compiled for three spatial units: (1) the estuarine drainage area; (2) U.S. Geological Survey hydrologic catalog units; and (3) counties that intersect EDAs. Population estimates are compiled for EDAs only. With these two volumes the NEI represents the most consistent and complete set of data ever developed for the Nation's estuarine resource base.

The Shellfish Program

Work on classified shellfish growing waters began with the *1985 National Shellfish Register of Classified Estuarine Waters* (FDA and NOAA, 1985), a compilation of classification of shellfish growing waters by state. Data were later reorganized by estuary, for all NEI estuaries (Broutman and Leonard, 1986). Additional information on administration of state programs, reasons for classification, pollution sources, and trends in classification were added to improve the utility of the data for assessing water quality in estuaries. Assessments are now complete for the Gulf of Mexico (Broutman and Leonard, 1985) and the East Coast. A report on West Coast waters will be completed in 1989.

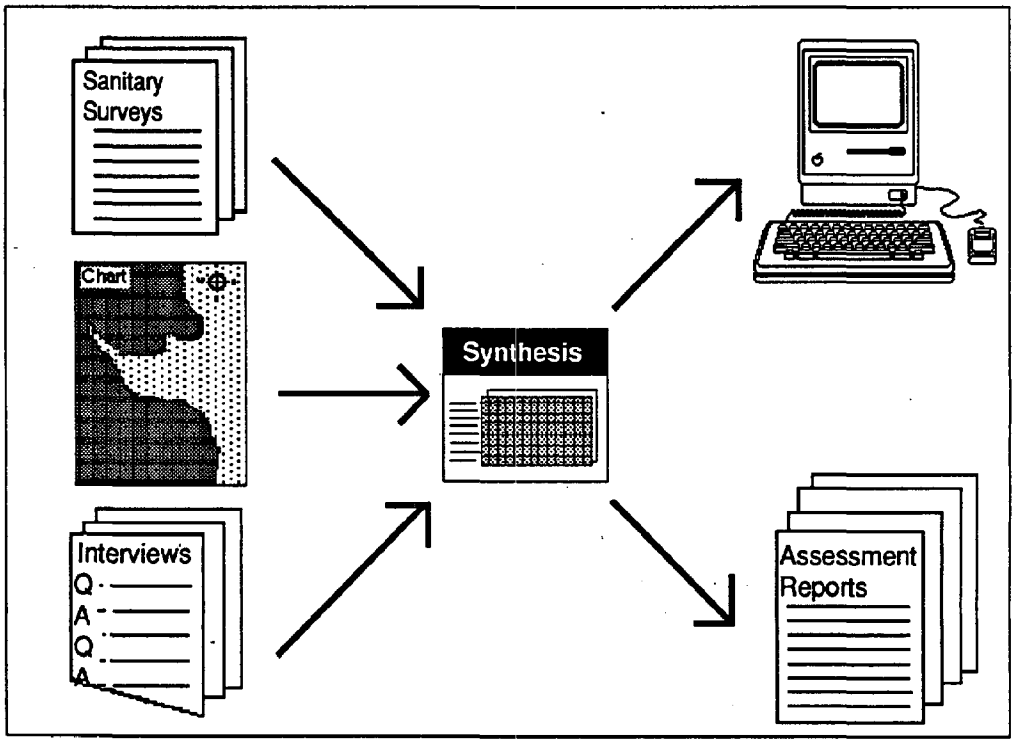
Preparing for the 1990 Register

Data collection for the *1990 National Shellfish Register of Classified Estuarine Waters* will begin in January, 1990. For the first time, data will be entered into a Geographic Information System (GIS). This system will store spatial information, calculate areas, print data onto nautical charts, and calculate changes in classification between 1985 and 1990. In preparation, 1985 data will be entered into a GIS. Updated information on administration of state programs and pollution sources will also be added to the Register data base.

The Quality of Shellfish Growing Waters on the East Coast of the United States

Dorothy L. Leonard, Marlene A. Broutman
and Kristen E. Harkness

March1989



National Oceanic and Atmospheric Administration
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Strategic Assessment Branch
11400 Rockville Pike
Rockville, MD 20852

Findings

Estuarine waters are classified for the commercial harvest of oysters, clams, and mussels based on presence of actual or potential pollution sources and coliform bacteria levels in surface waters. To protect the public health of shellfish consumers, harvest limitations are placed on waters that may be potentially contaminated with pathogenic bacteria or viruses.

The Quality of Shellfish Growing Waters on the East Coast provides consistent information on health and use of coastal waters for national and regional level decisionmakers. This work examines the status of classified shellfishing waters in 1985, trends in classification from 1971 to 1985, and pollution sources affecting shellfishing waters. Data were compiled through interviews with state shellfish control agency personnel responsible for classifying waters and through reviews of written materials. Major findings of this study are:

Status

- 82 percent of shellfishing waters on the East Coast were approved for harvest in 1985.
- 18 percent of East Coast waters were harvest-limited: 14 percent were prohibited to harvest at all times; 2 percent were conditionally approved (may be harvested under some conditions); and 3 percent were restricted (may be harvested if shellfish are purified before marketing).
- The large percentage of approved waters on the East Coast (82 percent) as compared to the Gulf (42 percent) and West Coast (30 percent) is mainly due to physical differences in the estuaries of these regions. About 50 percent of approved waters on the East Coast are large, open water, nonproductive areas associated with large estuarine systems (Long Island Sound, Chesapeake Bay, and Pamlico Sound).
- The Mid-Atlantic subregion had the highest percentage of approved waters (90 percent). The Northeast was 77 percent approved and the Southeast was 75 percent approved.

Trends

- Efforts to assess trends in classified waters from 1971 to 1985 fell short because states often reclassified areas after improving monitoring efforts (e.g., sampling in areas that were not previously sampled, or sampling under worst case conditions) rather than as a result of actual declining or improving water quality.
- Less than half of the changes in classification in the Northeast and Mid-Atlantic subregions could be related to changes in water quality. Major changes in the administration of shellfish programs in South Carolina, Georgia, and Florida accounted for almost all classification changes in these states.

Pollution Effects

- The 1.5 million acres of harvest-limited waters on the East Coast were affected by ten types of pollution sources.
- In the Northeast, the major contributing sources were associated with urban areas: sewage treatment plants affected 413,000 acres or 80 percent of harvest-limited waters in the subregion; combined sewers and urban runoff each affected over 275,000 acres (54 percent).
- In the Mid-Atlantic, causes of shellfish bed closures reflect a more suburban or rural character, i.e. only 52 percent attributed to wastewater treatment facilities and 42 percent to urban runoff. Other sources affecting Mid-Atlantic waters were boating activities and marinas (47 percent), wildlife (23 percent), agricultural runoff (17 percent), and septic systems (17 percent).
- The Southeast is predominantly rural: sewage treatment facilities are identified as a contributing source in only 44 percent of harvest-limited waters, and urban runoff in only 27 percent. Agricultural runoff (37 percent), wildlife (29 percent), septic systems (16 percent), and boating activities (12 percent) are important sources in the Southeast subregion.

Table of Contents

List of Tables and Figures

Table

Figure

Introduction

More than eight million acres of estuarine waters on the East Coast of the United States are classified for the commercial harvest of oysters, clams, and mussels based on public health concerns. These molluscan shellfish are filter feeders, capable of pumping large volumes of water through their systems and accumulating particles or pollutants present in water. Bacterial or viral pathogens may accumulate in shellfish tissue and digestive systems and may be passed to humans who consume partially cooked or raw shellfish. To protect public health, harvest for human consumption is not allowed in waters that are near potential pollution sources or contain high levels of coliform bacteria. While coliform bacteria are not harmful, they are measured in water to indicate possible presence of pathogenic bacteria and viruses of sewage origin.

This report examines the quality of shellfishing waters in estuaries along the East Coast. Section I provides background information on shellfish-borne diseases and the *National Shellfish Sanitation Program* (NSSP). Land use and regional characteristics of three subregions, the Northeast, Mid-Atlantic, and Southeast, are described because of their influence on classification. A shift in production of molluscan shellfish from the Mid-Atlantic to the Gulf of Mexico and Florida's East Coast is identified. State shellfish programs are described in terms of the budget, staffing, and other resources committed to classifying waters.

Section II examines the status of classified shellfishing waters, showing that 82 percent of waters on the East Coast are approved for harvest; although half of this is not naturally productive. An examination of trends in classified waters from 1971 to 1985 concludes that classifications are often changed because of administrative factors, such as increased monitoring, rather than because of improvements or declines in water quality. Improvements in sewage treatment have opened some waters to harvest, whereas increased use of the coastal zone for housing and recreation has closed waters.

Section III identifies the sources of pollution affecting classified waters in the three subregions. Sewage treatment plants, combined sewers, and urban runoff are the major contributing factors in restricting harvest in shellfishing waters of the highly urbanized Northeast. In the less developed estuaries of the Mid-Atlantic and Southeast, boating, agricultural runoff, and wildlife affect shellfishing waters.

American Oyster *(Crassostrea virginica)*

Public health concerns for consumers of shellfish in the United States have existed since early colonial times when shellfish were an important staple of the diet. Early settlers gathered a bountiful harvest of oysters and clams from coastal estuaries. However, by 1658, the Dutch Council of New Amsterdam, concerned about the depletion of the resource, passed an ordinance regulating the harvest of oysters from the East River. Although most early legislation (New York, 1715; New Jersey, 1730; and Rhode Island, 1734) was designed to regulate shellfish harvesting, presumably as a conservation measure, it also succeeded in protecting public health in waters affected by wastes from concentrated human populations.

By the early twentieth century, illnesses associated with the consumption of raw oysters, clams and mussels were on an increase. In 1924, following an outbreak of typhoid fever traced to oysters contaminated by sewage, public health authorities requested action by the Surgeon General of the U.S. Public Health Service (PHS). A conference of public health officials, meeting in February 1925, formulated a program of public health controls including the issuance of "certificates" (permits to operate) to shellfish shippers. This program, the *National Shellfish Sanitation Program* (NSSP) is now administered as a cooperative effort between states, industry, and the Federal government through the Interstate Shellfish Sanitation Conference (ISSC). Under the NSSP, the Food and Drug Administration (FDA) appraises each state's shellfish program to determine if their procedures are consistent with the current Manual of Operations (Interstate Shellfish Sanitation Conference, 1986).

Shellfish-borne Illnesses

The NSSP is based on the assumption that a relationship exists between sewage pollution of shellfish growing areas and human disease. Pathogens are transmitted through a fecal-oral route and may enter the waters through direct discharges of untreated or poorly treated human wastes. Bivalve molluscs, such as oysters, clams, and mussels are filter feeders. These organisms strain food and particulate matter that is carried to their location by currents. Because they filter large volumes of water relative to their size, molluscan shellfish may concentrate pollutants and pathogens that may be present in the water.

Enteric Pathogens. The major enteric diseases associated with consumption of shellfish from sewage-contaminated waters are hepatitis A, Norwalk virus, and nonspecific gastroenteritis. Nationwide, reported incidences of these viral diseases have increased in recent years, while bacterial illnesses have declined (Richards, 1985). Since 1954, there have been no reported outbreaks of typhoid fever, a bacterial illness and the predominant shellfish-borne disease of the early twentieth century.

A recent report by the U.S. General Accounting Office (1988) concluded that illnesses associated with the consumption of molluscan shellfish for the period 1979 to 1982 accounted for only 2.5 percent of all food-borne illnesses. However, shellfish from the East Coast have been implicated in more than 900 cases of hepatitis and over 2,000 cases of gastroenteritis since 1961 (Richards, 1986). In 1982, outbreaks of shellfish-borne gastroenteritis reached "epidemic" proportions in New York State, with 103 documented outbreaks in which 1,017 people became ill (Morse, 1985). Norwalk virus was identified as the cause of disease in the New York outbreaks. The shellfish were traced to coastal waters of several northeastern states. Since the early 1980s the states have increased monitoring efforts and the industry has undertaken national education programs for both the shellfish handler and the consumer in order to reduce the incidence of shellfish-borne disease.

Marine Biotoxins. Coastal waters are occasionally affected by blooms of toxin-producing plankton, that, when ingested, may lead to nervous system disorders or death. These blooms are often referred to as "red tides" and occur in all regions of the U.S. During blooms, large quantities of toxin-producing organisms are ingested by shellfish that become highly toxic to humans. Occurrence and transport of red tides are related to physical factors, including temperature, salinity, currents, and tides. In deep water, a biological clock may transform the organism from an inactive cyst that settles to the bottom of the water column to an active form. In shallow water, temperature and light are controlling factors in dormancy and blooms.

The majority of shellfish-growing states have developed management plans to control the monitoring and closure of growing waters during toxic blooms. These management plans are separate from those developed to control harvest of sewage-contaminated shellfish. Under the NSSP,

state shellfish control agencies regularly collect and assay samples of shellfish from growing areas where the blooms are likely to occur. If the toxin level reaches 80 micrograms per 100 grams of the edible portions of raw shellfish meat, the area is closed to harvest and the public advised against harvest and consumption from designated areas. The management of marine biotoxins is an intensive and expensive responsibility for affected states. For example, Maine spends over $150,000 per year for biotoxin monitoring activities, as compared to $150,000 for laboratory services and $66,500 (1985) for shellfish sanitation activities.

Northeast waters are primarily affected by *Protogonyaulax tamarensis*, a dinoflagellate that produces a neurotoxin in shellfish that can result in paralytic shellfish poisoning (PSP). PSP produces symptoms within 30 minutes, including a burning sensation of the lips, gums, and tongue, and may progress to numbness, possible loss of motor coordination, muscular paralysis, and death. Maine was the first state to develop a PSP management plan in 1958 following an outbreak of 20-30 cases in 1957. In 1980, there was an estimated loss in excess of $7,000,000 due to recurrent costs associated with preventative shellfish monitoring programs (Shumway, *et. al.*, 1988). In 1972, Massachusetts found high levels of toxin in shellfish resulting from a bloom of *P. tamarensis* and subsequently closed shellfishing areas. Connecticut took similar actions in 1985.

Southeastern waters are affected by a different type of dinoflagellate, *Ptychodiscus brevis*. *P. brevis*, first identified in waters off the west coast of Florida in 1844, was transported via the Florida current and Gulf Stream to North Carolina in the 1987 and South Carolina in 1988. In North Carolina, the red tide event closed 98 percent of clam and 50 percent of oyster harvesting areas in the State's southern and central waters, resulting in economic losses estimated at $2.3 million (Tester and Fowler, in preparation). *P. brevis* produces several neurotoxins that accumulate in filter-feeding shellfish and, although not fatal to humans, can cause neurotoxic shellfish poisoning (NSP), respiratory irritation in humans and finfish, shellfish toxicity, and fish kills. Shellfish control agencies in both North and South Carolina have developed NSP management plans to monitor concentrations, close shellfish areas when quarantine levels are reached, and alert the public.

Another marine biotoxin disease, diarrhetic shellfish poisoning (DSP) has occurred in other countries. Although the suggested causative organism, *Dinophysis fortii*, has been found in US waters, no confirmed illnesses have been reported. The symptoms closely resemble gastroenteritis caused by sewage-associated viruses and are difficult to diagnose. A recent study by Stamman, *et. al.* (1987) concluded that the outbreaks of gastroenteritis in the New York area were more likely viral diseases than DSP because onset times were longer than 12 hours (the onset time for DSP). There have been no closures based upon the incidence of DSP and none of the states interviewed routinely monitor for the occurrence of *Dinophysis*.

The National Shellfish Sanitation Program

The NSSP ensures the safety of shellfish for human consumption by preventing harvest from waters that may contain pathogenic organisms or other contaminants. Waters are classified into one of four categories (Table 1) based on presence of actual or potential pollution sources, and levels of coliform bacteria levels in surface waters. In accordance with NSSP guidelines, each state classifies their waters following sanitary surveys that: (1) identify actual or potential pollution sources that may affect shellfish growing waters (a "shoreline survey"); (2) evaluate hydrologic and meteorological conditions affecting pollutant transport; and (3) sample waters for bacteriological quality.

Table 1. Definition of Classifications

Classification	Description
Approved	Waters may be harvested for the direct marketing of shellfish at all times.
Conditionally Approved	Waters do not meet the criteria for approved waters at all times, but may be harvested when criteria are met.
Restricted	Shellfish may be harvested from restricted waters if subjected to a suitable purification process.
Prohibited	Harvest for human consumption cannot occur at any time.

The term *"harvest-limited"* is used to refer to conditionally approved, restricted, or prohibited waters. A closure area is an area in which some restriction on harvest has been placed, e.g. a harvest-limited area.

The NSSP standard for approved waters is either a median or geometric mean total coliform bacteria concentration of less than 70 Most Probable Number (MPN) of cells per 100 milliliters (mL), with no more than 10 percent of the samples exceeding 230 MPN per 100 mL; or a fecal coliform standard of 14 MPN per 100 mL, with no more than 10 percent of the samples exceeding 43 MPN per 100 mL (Interstate Shellfish Sanitation Conference, 1986). MPN is a statistical test for determining number of bacteria. The fecal coliform standard more specifically indicates presence of fecal material.

The total and fecal coliform standards are used routinely to ascertain the possible presence of enteric pathogens. However, evidence suggests that these standards are not reliable as indicators of viral pathogens because enteric (intestinal) viruses are more resistant than coliforms to temperature and chlorination, and may accumulate and depurate in the host at different rates. Although it is accepted by state health departments that guidelines restricting the levels of enteric virus contamination in shellfish would reduce the incidence of shellfish-borne disease, the research to ascertain the most effective indicators has not yet been conducted.

Waters that do not meet approved standards may be harvested under certain conditions. A management plan clearly defines predictable periods during which conditionally approved waters meet approved standards and may be harvested. In general, East Coast conditional areas are opened to harvest except after rainfall when runoff transports coliform bacteria to surface waters. Conditionally approved areas in New Jersey are closed to harvest in summer when use of coastal beaches and marinas increases. One conditional area in Florida is managed based on salinity as well as rainfall.

Shellfish from restricted waters must be purified, through depuration or relaying, before harvesting for human consumption. In depuration, shellfish are placed in tanks where bacteria-free water is circulated, usually for 48 hours. The water is purified with ultraviolet light or ozone. Depurated shellfish are tested for bacteria levels before being released for market. In relaying, shellfish are transferred to approved waters and remain there for at least fourteen days prior to harvest for human consumption. Relaying shellfish from prohibited to approved waters also occurred until 1986, when the practice was disallowed by the revised NSSP Manual of Operations (Interstate Shellfish Sanitation Conference, 1986).

Regional Characteristics

The report has been organized by three East Coast subregions: 1) the Northeast, including 22 estuaries in the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and northern New Jersey; 2) the Mid-Atlantic, including 12 estuaries in New Jersey, Delaware, Maryland, and Virginia; and 3) the Southeast, including 21 estuaries in North Carolina, South Carolina, Georgia and Florida (Figure 1). New Jersey is the only state to be divided into two subregions. The 55 estuaries examined in this report represent approximately 95 percent of the total estuarine surface area on the East Coast.

Northeast. The Northeast subregion extends from Passamaquoddy Bay in Maine through the Hudson River/ Raritan Bay system. A region of cities, its natural resource base is stressed by a population in excess of 37 million. Although the population increase for the Northeast was a low 0.3 percent (1970-1980), a few estuarine areas registered significant population jumps, including Cape Cod Bay (57 percent), Narraguagus Bay (31 percent), Saco Bay (23 percent), and Great Bay (24 percent). This growth reflects an increasing demand for coastal development and recreational opportunities in close proximity to urban areas.

Land use in the Northeast has its origins in historic settlement patterns and economic forces that shaped the location of transportation, industry, and agriculture. Major population centers of New England are located near the coast, close to major ports and industries dependent upon ocean transport. Despite the large metropolitan areas in this region, urban land is dominant in the estuarine drainage area of only Boston Bay and Great South Bay. Urban land use ranks third behind forest and agricultural activities in the Northeast region. This is the case even in the Hudson River/Raritan Bay Estuary where the human population approaches 12 million and complex industrial patterns/public infrastructure support the huge New York metropolitan area. Forest and agricultural lands upstream from this urban center account for nearly 75 percent of land use in this estuarine drainage area. Forests account for an average of 80 percent of the estuarine drainage areas in 15 Northeast estuaries.

Mid-Atlantic. The Mid-Atlantic subregion, as defined for this project, extends from the Barnegat Bay estuary in New Jersey to the southernmost reach of Chesapeake Bay in Virginia. Settlement

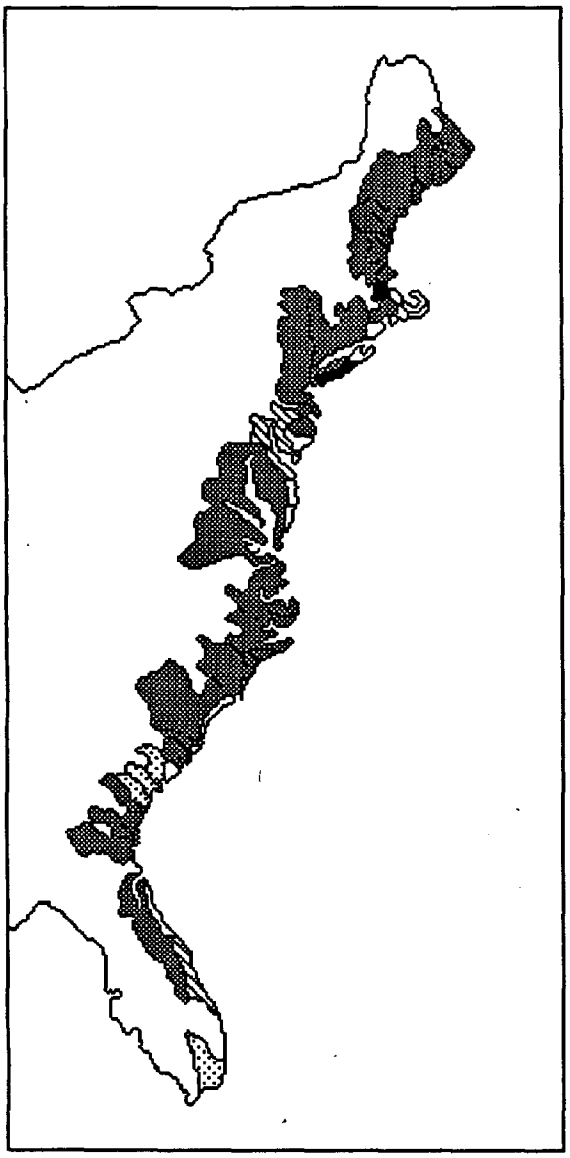


Figure 1. Predominant land use in the East Coast region

and land use in this region were influenced significantly by the historical head of navigation, or "fall line" separating the coastal plain from the Piedmont physiographic province. Examples are the Delaware, Potomac, and James Rivers where cities such as Trenton, New Jersey; Washington, DC; and Richmond, Virginia were founded. Although Delaware and Chincoteague Bays experienced a decline in population (1970-1980), significant population growth occurred in Barnegat Bay (47 percent), as well as the York (40 percent) and Rappahannock rivers (27 percent), subestuaries of the Chesapeake Bay. Agricultural land use is still predominant in the subregion, occupying over 30 percent of the estuarine drainage areas of the Delaware, Chincoteague, and Chesapeake bays. The Northeast megalopolis now extends in a continuous span of urban area from Portland, Maine, to Norfolk, Virginia, with increasing pressures for recreational opportunities and supporting infrastructure crowding the historic activities such as agriculture and fishing. Shellfish resources are stressed and declining in density throughout the Mid-Atlantic estuaries.

Southeast. The Southeast subregion stretches from Albemarle Sound in North Carolina to the Indian River in Florida. Of the three subregions, the Southeast has estuaries that are the least populated. Major urban areas are located directly on the coast (the seaports of Charleston, South Carolina, and Savannah, Georgia) or along historic heads of navigation (*e.g.* Raleigh, North Carolina and Columbia, South Carolina). Despite its low population, the Southeast grew rapidly between 1970 and 1980 due to increases in light industrial activity and pulp and paper production. Of greater impact on shellfisheries is the rapidly expanding tourism and vacation home development. Unlike the urban areas of the Northeast, where cities radiate out from inner cores, residential development, particularly in Florida and North Carolina, has spread along the narrow coastal strip in a series of suburban, vacation home, and condominium developments. All of the estuarine drainage basins in the Southeast have experienced growth ranging from almost ten percent in New River, North Carolina, to over 50 percent in St. Catherines/Sapelo Sound.

Extensive wetlands, agriculture, and pine forests are the outstanding features of the land surrounding estuaries of the Southeast. Forested land is dominate in 13 of the estuaries, and comprises 40 percent of the Nation's commercial forest. Wetlands cover over 25 percent of the estuarine drainage areas in the Southeast — the greatest wetland density of any coastal region or subregion in the country. Two well-known and extensive wetland areas are the Dismal Swamp in Virginia and the Okefenokee Swamp in Florida. A dramatic wetlands feature of the subregion is the Sea Islands complex of South Carolina and Georgia, a vast area of intricate estuarine channels and marshlands about seven miles wide at the mouths of St. Helena Sound, Broad River, Savannah River, Ossabaw Sound, St. Catherines/Sapelo Sound, Altamaha River and St. Andrews/St. Simons Sound.

The East Coast Shellfish Industry

Molluscan shellfish harvested in East Coast estuaries include the hard clam or quahog *(Mercenaria mercenaria)*, soft-shell clam *(Mya arenaria)*, American oyster *(Crassostrea virginica)*, and bay mussel *(Mytilus edulis)*. Soft-shell clams predominate from Maine to Massachusetts, hard clams from Rhode Island to New Jersey, soft shell clams and oysters in the Mid-Atlantic, and oysters and hard clams in the Southeast. Although this report concerns the quality of shellfishing waters in estuaries, the inclusion of information on oceanic species is necessary (Figure 2), not only because of their economic importance, but also to address the issue of classifying ocean waters. New Jersey classifies 280,000 acres of oceanic waters, some of which are adjacent to outfalls from regional wastewater treatment plants. The NSSP requires that states establish a buffer or "safety zone" around sewage treatment outfalls classified as prohibited. Other coastal states are also considering ocean outfalls as a possible solution to the cleanup of productive estuaries. Presumedly, they will then classify those waters as prohibited. Ocean species, prevalent from New Jersey through Virginia, include the ocean quahog *(Arctica islandica)* and surf clam *(Spisula solidissima)*.

The Mid-Atlantic subregion led the Nation in landings of oysters and clams until the early 1980s (Figure 3). In recent years the industry has declined, forcing watermen out of the industry or redirecting harvesting efforts in Chesapeake Bay to soft-shell clams and blue crabs and, in New Jersey, to surf clams and ocean quahogs. Rising demand for shellfish has been met by imports (NOAA, National Marine Fisheries Service, 1987) and by increasing production along the Gulf Coast. Reductions in harvestable shellfish resources in the Northeast and Mid-Atlantic subregions is attributed to overharvesting, disease, predation, and environmental impacts.

Overharvesting. Hargis and Haven (1988) report that overharvesting from publicly owned and managed grounds was the single most important factor in the decline of Virginia's oyster production. The report attributes the decline to oystermen who, since the early 1900s, have consistently taken more market oysters from public bottoms than were replaced. Overharvesting is a major factor in the Northeast as well. In Great South Bay, hard clam landings dropped dramatically as a result of overharvesting from over 700,000 bushels in 1976 to less than 105,000 in 1986 (Kassner, 1988).

Disease. Lewis (1987) argues that although pollution and overharvesting are important, diseases are the predominant reason for recent declines in shellfish production in the Mid-Atlantic region. The parasitic diseases MSX *(Haplosporidium nelsoni)* and dermo *(Perkinsus marinus)* have thrived in recent drought years as high salinity waters have

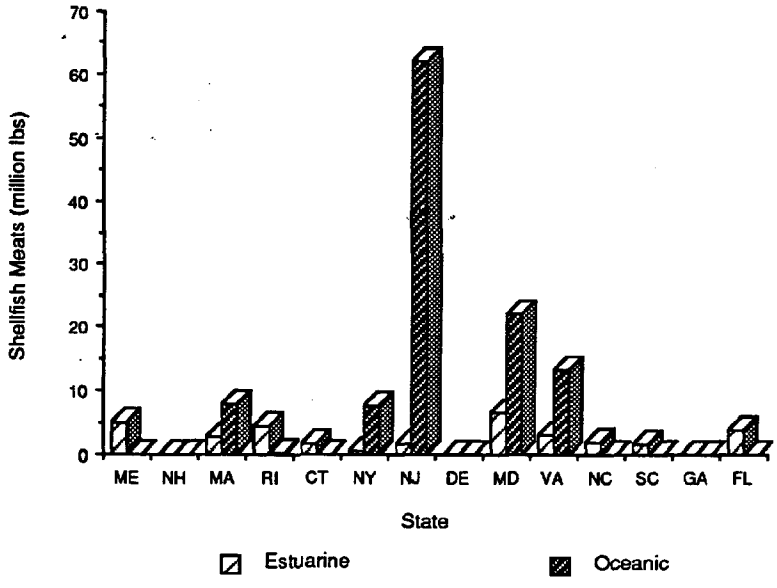


Figure 2. Landings of clams and oysters, 1985

spread to upper areas of the estuaries. In the wake of MSX, private oyster-growing leaseholders reduced their planting efforts, resulting in consistent low levels of oyster production from leased beds. These low levels of oyster production from leased beds will continue until growers are willing to risk new plantings. Work is in progress at Rutgers University and Maryland's Oxford Laboratory to develop disease resistant oysters. However, to date this work has produced only limited successes, and the hope that disease resistant oysters will solve the problems of the Mid-Atlantic shellfishery in the near future is small.

Predation. Another major cause of declining shellfish populations is predation, particularly during larval or juvenile life stages. Oyster predators are numerous in high salinity areas such as Long Island Sound and lower Chesapeake Bay. In Long Island Sound, major predators are starfish and oyster drills. In addition, slipper shells kill spat by competing for attachment surfaces or growing over them. Barnacles are also lethal competitors (Grosslein and Azarovitz, 1982). In more southern estuaries the oyster drill is the major predator, boring a hole through the shell and extracting the meats. Chesapeake Bay oysters are also preyed upon by anemones, blue crabs, starfish, cow-nosed rays, and moon snails which feed on both juvenile and adult oysters. Some species of finfish feed on free swimming larvae as well as adult shellfish. Fish and other invertebrates are abundant on oyster beds, using the oysters to provide attachment and hiding places. Clams are preyed upon by gastropods, crabs, starfish and some species of finfish. If not controlled, predation can eliminate shellfish populations. Predators can be controlled by pesticides, although their use is often prohibited.

Pollution. Dredging activities and pollution have also been implicated in the decline of shellfish resources. The most obvious effect of pollution is the reduced availability of traditional oyster grounds and clam beds because the shellfish may be contaminated with bacteria and viruses from domestic sewage. Sublethal effects of heavy metals, pesticides, and petroleum residues have been identified in laboratory experiments. For example, silver in concentrations as low as 0.1 ppm alters oxygen consumption in bivalves (Thurberg, *et. al.*, 1974). Petroleum contaminants reduce fertilization of oyster eggs (Renzoni, 1973). At the larval stage, oysters are extremely sensitive to pollutants such as detergents, pesticides, herbicides, and heavy metals. (Davis, 1961; Calabrese and Davis, 1976; Calabrese *et. al.*, 1982). Effects of pollutants are more difficult to identify in the natural environment. Acute toxic effects on oyster larvae from chloramines were observed in Virginia waters on the James River. Chloramines are formed when chlorine from treated sewage effluents and cooling waters reacts with nitrogenous compounds found in sewage. Chloramines are particularly toxic when mixed with seawater. Increased nitrogen levels from agricultural

Figure 3. Landings of clams and oysters, 1965-1984

runoff and sewage effluent lower oxygen levels, causing shellfish mortality. In 1976, anoxia destroyed 140,000 tons (69 percent) of New Jersey's offshore surf clams, valued at approximately $123 million (Figley, *et. al.*, 1979).

Landings in the Southeast, although small compared to the other regions, are on the increase in recent years. Florida hard clam landings, increased from 60,000 pounds in 1976 to 1.7 million in 1984 (Busby, 1986), and 3.5 million pounds in 1985 (M. Berrigan, personal communication). The rises in Florida clam populations are attributed to increased salinities favorable to clams and increased nutrients entering waters from human activities and heavy rainfalls in 1982, 1983, and 1984. Other factors affecting the growth of the hard clam industry are the increase in state-approved purification activities, including relaying and depuration (see glossary).

The economic success of the Florida clamming industry has attracted large numbers of northern harvesters who move south during winter months. In Suffolk County on Long Island, hard clam landings declined 76 percent between 1976 and 1985, resulting in loss of jobs, diminished economic impact on local economy, and erosion of the county's position as a leading producer of hard clams in the United States. The decline was caused by overfishing, illegal harvest of seed clams and clams from uncertified areas, changes in bay salinity, reduced reproductive success, and deteriorating water quality resulting in closures of harvest grounds (Suffolk County Planning Department, 1987). Many of the Suffolk County harvesters have relocated to the Indian River in Florida. Florida laws do not prevent out-of-state clammers from entering the fishery before establishing residency, but the resentment of the local fishermen and the additional pressure on the fishery may alter requirements.

Administration of State Programs

Availability of financial resources, professional staffing, and equipment has a direct impact on state efforts to classify shellfish growing waters. A questionnaire was used to collect information on the administration of state programs, including budgets, staffing, sampling and shoreline survey procedures. Data reflect resources that are used to monitor and classify all shellfishing waters in each state. Information was also collected on the budget and personnel for laboratories, seafood plant inspections, and management of shellfish resources. Resource requirements vary from state to state depending on physical characteristics of the estuaries, such as miles of shoreline, and how waters are classified, with conditionally approved waters generally requiring the most resources. East Coast states (except New Jersey) classify only estuarine waters. New Jersey also classifies 280,000 acres of open oceanic waters.

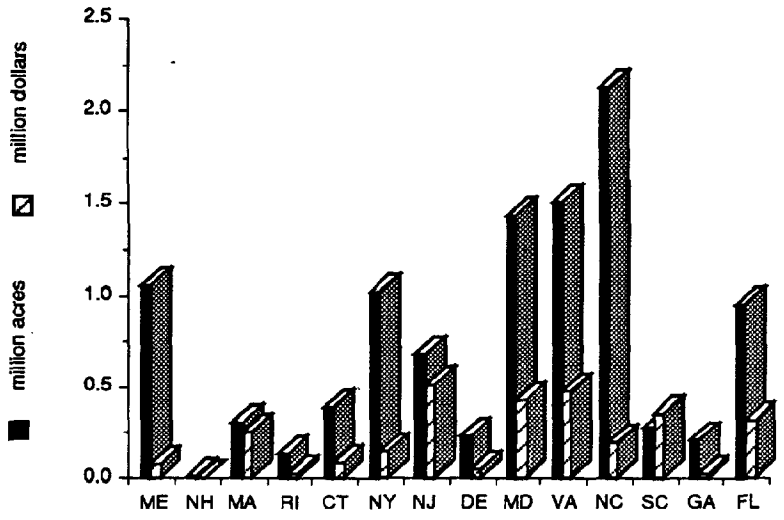


Figure 4. State budgets for classifying waters, 1985

About 2.5 million dollars are spent by East Coast states to survey and classify waters (Figure 4). Most spend 10 to 30 cents per acre; however, some states spend much more. South Carolina spends more than one dollar per acre, and Massachusetts and New Jersey spend 80 and 75 cents per acre, respectively. Some East Coast states have continually well-supported programs (New Jersey, Maryland, Virginia, and South Carolina), while others have managed within limitations imposed by shrinking state budgets and limited political support (Maine, New Hampshire, Rhode Island, Connecticut, New York, Delaware, and North Carolina). In Maine, monitoring and laboratory activities must focus on marine biotoxins during the spring and summer, reducing the resources available for bacteriological work.

East Coast states monitor for levels of total or fecal coliform bacteria at 20,000 sampling stations, or about one station for every 510 acres of growing waters. Massachusetts and New Jersey lead in unit number of sampling stations: one per 240 acres in the former and one per 170 acres for the latter (Figure 5). Some of these stations are permanent locations with regularly scheduled sampling. Others are established to monitor conditionally approved waters or in an effort to improve classifications where pollution sources have been cleaned up.

The NSSP guidelines suggest that a minimum of five water samples be taken annually at each station. In most cases the states far exceed this requirement with monthly sampling the norm. Water samples are taken near the surface and often include other parameters such as salinity and temperature. Weather conditions are noted since the samples should reflect water quality after major pollution events such as heavy rainfall and high river stage. States may also note presence of birds or boats in the area.

Recent Developments. Since 1985, the base year for this report, several states have made substantial changes in their shellfish programs. In November 1985, Massachusetts Marine Fisheries published a White Paper outlining economic, environmental, and management problems facing commercial and recreational fisheries. The shellfish program has since been reorganized, resulting in improved monitoring and shoreline surveys. Georgia has added staff and increased their monitoring and survey activities. Connecticut has increased support for aquaculture development; however, the state has not conducted shoreline surveys and monitoring necessary to classify productive waters. Thus Connecticut's newly developed oyster industry is unable to harvest matured oysters from waters that are still classified prohibited. North Carolina faced a bloom of *Ptychodiscus*

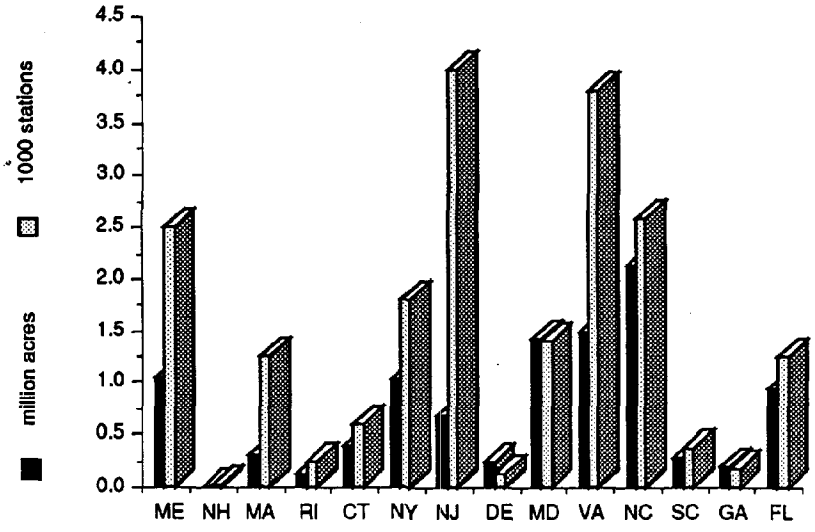
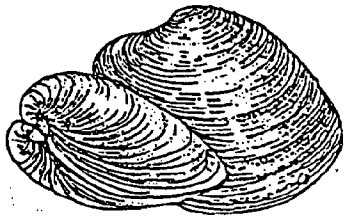


Figure 5. Number of sampling stations by state

brevis in 1987 that stressed limited resources, adversely impacting the bacteriological monitoring and shoreline survey efforts. The North Carolina legislature is considering reorganizing and expanding the State's shellfish program.

State shellfish control agencies are adapting more sophisticated methods for managing conditionally approved waters. Management plans must clearly define the conditions under which these waters will be opened or closed to harvest. The most advanced system is used by Florida, where the Department of Natural Resources (DNR) has contracted with the U.S. Geological Survey (USGS) to install and maintain a permanent monitoring station in the Intracoastal Waterway near Indian River. The station consists of a solar panel, conductivity and temperature probes, and water level and rainfall gauges. An on-site data logger collects the probe and gauge data and transmits it via antenna to a GOES satellite. The information is transferred by USGS to DNR computers every 15 minutes. The Indian River Management Plan requires closure of the growing area if one inch or more of rain falls within a 24 hour period or if the salinity drops below 26.3 parts per thousand (ppt). The first year cost was $31,000 with $14,000 in maintenance and operation costs for each ensuing year. Limited resources prevent most states from installing systems similar to the test station in Florida.

In Maryland, conditionally approved waters are closed to harvest on the basis of rainfall. An elaborate management plan relies on volunteers to report rainfall information to the agency. Additional information on tides and stream levels are obtained from NOAA and USGS, respectively. The large resources required to predict environmental thresholds by analyzing comprehensive data bases, as well as to obtain current environmental information, prevent many states from classifying areas as conditionally approved.



Hard Clam *(Mercenaria mercenaria)*

This section examines the status of classified shellfishing waters as of 1985 and trends in classification between 1971 and 1985. Classification data were derived from charts of the 1985 and 1971 versions of the *National Shellfish Register of Classified Estuarine Waters*. Data were clarified through interviews with state agency personnel and reviews of written materials.

1985 Classification of East Coast Waters

About 6.6 million acres, or 82 percent of East Coast classified waters were approved for harvest of molluscan shellfish in 1985 (Table 2). Two-thirds of this approved area is found in the three largest East Coast estuaries: Chesapeake Bay (2.4 million acres approved shellfishing waters), Pamlico Sound (1.3 million acres), and Long Island Sound (0.7 million acres). Much of the approved area is not productive because of extreme salinities, or lack of suitable depth, substrate, or habitat for molluscan shellfish. The open water areas of Chesapeake Bay, Long Island, and Pamlico sounds are largely nonproductive and are on the order of 50 percent of the total approved shellfishing waters on the East Coast.

Eight estuaries in the region had no approved shellfishing waters. These were either small river systems (*e.g.* Altamaha River) or highly urbanized areas such as Boston Bay, Hudson River/Raritan Bay, and Charleston Harbor.

Of the three subregions, the Mid-Atlantic had the most approved waters (2.9 million acres, or 90 percent of classified shellfishing waters). Surprisingly, the Southeast with a coastal population of only 7.5 million and considerable undeveloped shoreline, had the lowest percentage of approved waters, 75 percent (1.9 million acres). The Northeast, with a coastal population of more than 20 million, had 1.75 million acres or 77 percent of classified waters approved for harvest.

Effects of Salinity and Freshwater Inflow. A comparison of 1985 classifications in the East Coast subregions to those of the Gulf and West coasts is shown in Figure 6. Classified shellfishing waters were 42 percent approved along the Gulf Coast and 30 percent approved on the West Coast, much lower percentages than the East Coast subregions. These large regional differences exist because physical characteristics of estuaries have

Table 2. Classification of East Coast estuaries, 1985

Estuary	Area Classified (acres)			
	Approved	Conditional	Restricted	Prohibited
Northeast				
Passamaquoddy Bay	33,590	13	0	6,126
Englishman Bay	56,485	222	804	1,997
Narraguagus Bay	55,555	41	0	1,290
Blue Hill Bay	71,144	0	704	2,896
Penobscot Bay	197,972	3,163	3,259	27,349
Muscongus Bay	41,940	2,099	575	1,507
Sheepscot Bay	35,962	2,310	1,933	23,116
Casco Bay	91,892	2,273	998	12,286
Saco Bay	9,849	0	1,379	1,581
Great Bay	3,599	0	548	8,671
Merrimack River	0	0	218	2,243
Massachusetts Bay	4,385	0	3,918	17,100
*Boston Bay**	0	0	3,853	11,533
Cape Cod Bay	45,812	213	0	3,160
Buzzards Bay	117,846	309	0	9,259
Narragansett Bay	70,226	11,179	0	24,343
Gardiners Bay	124,094	31	0	2,288
Long Island Sound	718,183	5738	0	134,912
*Connecticut River**	0	0	0	4,951
Great South Bay	75,593	547	0	26,578
Hudson River/Raritan Bay	0	0	20,188	144,211
Northeast total	1,754,127	28,138	34,520	450,913
% of Northeast classified area	77	1	2	20
Mid-Atlantic				
Barnegat Bay	37,958	6,034	0	10,218
Little Egg Harbor	24,801	2,423	0	2,,038
Reed/ Absecon Bays	14,299	4,607	64	7437
Cape May Bays	3,733	360	903	9,607
Delaware Bay	351,040	6,274	0	41,419
Delaware Inland Bays	12,269	3,348	0	3,548
Chesapeake Bay	2,377,394	32,933	111,667	65,43
*Potomac River**	252,846	1,364	3,225	3,102
*Rappahannock River**	70,810	89	4,263	0
*York River**	32,682	212	5,481	0
*James River**	45,461	15,018	82,959	9,105
Chincoteague Bay	98,815	0	0	724
Mid-Atlantic total	2,920,309	55,979	112,634	140,427
% of Mid-Atlantic classified area	90	2	3	4
Southeast				
Albemarle Sound	351,445	0	0	253,703
Pamlico Sound	1,264,095	5,519 a/	0	101,610
*Pamlico/Pungo Rivers**	52,325	0	0	60,657
*Neuse River**	75,071	2,288 a/	0	35,840
Bogue Sound	42,083	25,413 a/	0	8,309
New River	0	13,412 a/	0	9,422
Cape Fear River	0	9,387 a/	0	17,717
Winyah Bay	398	292 a/	0	18,720
Charleston Harbor	0	5,059 a/	0	19,009
North & South Santee Rivers	2,693	0	0	3,927
St. Helena Sound	51,137	0	0	602
Broad River	70,962	71	0	8,844
Savannah Sound	4,706	0	0	12,276
Ossabaw Sound	7,594	0	14,,467	0
St. Catherines/Sapelo Sounds	76,031	0	37020	864
Altamaha River	0	0	2,526	0
St. Andrew/Simons Sounds	43,617	0	5,933	31,350
Indian River	22,002	19,972	0	26,071
Southeast total	1,936,963	79,125	59,946	512,424
% of Southeast classified area	75	3	2	20
East Coast total	6,611,399	163,242	207,100	1,103,764
% of East Coast classified area	82	2	3	14

*Italicized estuaries are subestuaries; estuary totals include value of subestuaries.
a/ Officially classified as approved or prohibited, but managed as conditionally approved.

a major influence on classification. Salinity is a prime determinant of classification. Coliform bacteria levels are inversely related to salinity; bacteria levels are high in fresh waters and very low in highly saline waters. Originally, scientists believed the bacteria died in saline waters. However, recent studies suggest that bacteria may persist under certain conditions, but their numbers may be underestimated using standard measurement techniques (Rhodes, *et. al.*, 1983; Anderson, *et.al.*, 1979).

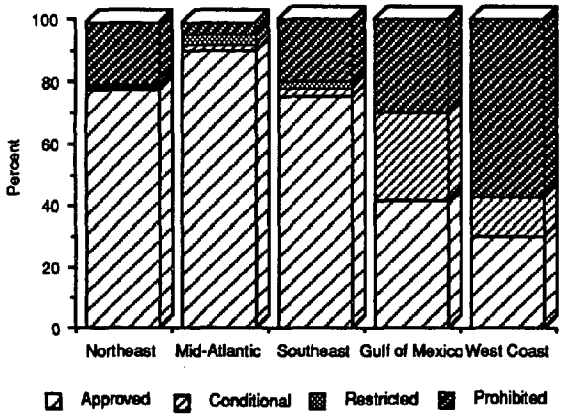


Figure 6. Classification by subregion, 1985

Salinity is related to many factors, including the size of the estuary and watershed; the amount of freshwater inflow from precipitation, runoff and rivers; and the influence of tides. In the Gulf, estuaries are smaller in size and tidal range than East Coast systems. Rivers entering the Gulf may reduce surface water salinity to near freshwater throughout an estuary. As a result, many estuaries are closed to harvest when river stages are high. On the East Coast, freshwater inflow effects are dampened by larger volumes of estuarine water and higher tides. For example, the Connecticut rivers entering Long Island Sound drain a highly populated watershed, but affect only small areas of the Sound. Albemarle Sound, the East Coast estuary with the greatest tidal fresh zone, is 42 percent prohibited. In neighboring Pamlico Sound, with similar land use characteristics but higher salinities, only eight percent of waters are classified as prohibited.

Harvest-Limited Waters. Waters that do not meet standards for approved status may be classified prohibited, conditionally approved, or restricted, depending on state preferences and water quality conditions. East Coast states used the prohibited classification most often, comprising 1.1 million acres or 14 percent of total classified areas (Table 1). These prohibited classifications are based upon the 1985 NSSP definition under which shellfish may not be harvested for market but may be relayed from these waters to approved or conditionally approved waters for at least two weeks and then harvested for human consumption. The 1986 revision of the NSSP Manual of Operations allows relaying only from restricted waters.

Waters are classified as conditionally approved if water quality changes are predictable and if waters are productive (productivity is needed to justify the additional cost and management requirements). Only two percent of East Coast waters were conditionally approved in 1985. By comparison, 27 percent of Gulf Coast waters were conditionally approved (this includes some Gulf waters that were officially classified as prohibited but managed as conditionally approved). Along the Gulf Coast, entire estuaries are closed to harvest when flooded by river systems, even those draining unpopulated watersheds. For example, the Mobile River has a large, but not highly developed drainage basin and is a greater source of coliform bacteria than the sewage treatment plants and urban runoff from the entire Mobile metropolitan area. Along the East Coast, rivers have less impact because of greater tidal ranges and larger volume systems. In Long Island Sound, where volume and salinity are high, pollution effects of the densely populated coastal communities, particularly along coastal Connecticut, are reduced as the rivers reach the Sound.

About 207,000 acres, or three percent of East Coast waters were classified as restricted in 1985. The restricted classification may be used when a sanitary survey shows that an area has a limited degree of pollution. Restricted waters from which shellfish are taken for depuration have a maximum acceptable coliform level (waters may not exceed a median coliform level of 700 MPN per 100 mL and not more than 10 percent of the samples may exceed 2,300 per 100 mL). Waters classified as restricted but not used for depuration have no associated coliform bacteria standard, leaving states to define conditions under which waters may be classified as restricted.

Depuration was developed in response to pollution problems in the more urbanized estuaries, such as Boston Bay and Hudson/Raritan. The depuration plant in Massachusetts, for example, was built in the 1920s and handles most of the harvest in the northern part of the State. Shellfish from about 34,000 acres of estuarine waters in Maine, Massachusetts, and New Jersey are purified at depuration facilities. Waters in these states are classified as restricted if depuration

is the intended use. Florida established standards and procedures for depuration plants after 1985 and has since reclassified some waters as restricted.

In Georgia and Virginia, waters are classified as restricted based on water quality considerations; these waters are not used for depuration and may or may not be used for relaying. In Georgia, waters that have reasonably good water quality and are not near pollution sources are restricted. These areas are generally found between the approved waters of the outer marshes and the prohibited areas of the upper regions of the estuary. In Virginia, 112,000 acres were classified as restricted, as compared to only 9,000 acres of prohibited waters (all in the Elizabeth River). Virginia classifies areas around sewage treatment plant outfalls as restricted; this is a violation of NSSP requirement fthat a closed safety zone around outfalls be classified as prohibited.

Classifications by Subregion

Northeast. Seventy-seven percent of shellfishing waters were approved for harvest in the Northeast subregion. However, four estuaries have no approved waters: Merrimack River, Hudson River /Raritan Bay, Connecticut River, and Boston Bay. Waters in New Hampshire, although classified, are not commercially harvested at the present time. Massachusetts classifies productive tidal flats of Boston Bay rather than waters of the estuary.

Studies conducted in Maine and Connecticut have estimated the amount of productive areas closed because of pollution. The Maine/New Hampshire Sea Grant Program (1983) estimated that nearly 30 percent of Maine's productive shellfish waters were closed to harvest in 1983 because of pollution problems. In 1980, 75 percent of Connecticut's 60,000 acres of productive shellfish beds were closed to harvest for water quality reasons (Connecticut Department of Environmental Protection, 1984).

Massachusetts has also estimated the area of productive waters that is harvest-limited (Massachusetts Division of Marine Fisheries, 1985). All productive waters in Boston Harbor are either prohibited or restricted. North of Boston, productive areas (intertidal flats with commercial quantities of soft-shell clams) are 45 percent prohibited and 15 percent restricted. Along the south shore, where oysters, mussels, and quahogs are also harvested, about 20,000 acres are classified as prohibited, of which 80 percent are productive. Economic losses from shellfish bed closures was estimated at $12.1 million, half of the $24 million in landings reported for Massachusetts' inshore shellfisheries in 1983.

Mid-Atlantic. In the Mid-Atlantic, 90 percent of the shellfish growing waters were classified as approved for harvest, the highest percentage of any region or subregion nationwide. Two percent of waters in the subregion were conditionally approved. Conditional waters in New Jersey are closed seasonally when people occupy summer homes along the beaches. Restricted areas were found in Virginia's waters of Chesapeake Bay and in Reed/Absecon and Cape May bays.

The Chesapeake Bay is the largest estuary in the Mid-Atlantic, comprising 2.6 million of the 3.2 million acres classified for shellfish harvest. Only about 36 percent of these classified waters provide potential shellfish habitat. Of the 1.3 million acres classified for harvest in Maryland, 530,000 acres are potentially productive. Oyster habitat covers approximately 230,000 acres, of which only 10 percent is currently productive. Ninety percent of these oyster grounds are in approved waters. Clam habitat is found in about 300,000 acres, but less than 20,000 acres are currently productive (George Krantz, personal communication, February 1989).

Of the 1.3 million acres of Chesapeake Bay classified by the State of Virginia, 413,000 acres are potentially productive. Public oyster grounds (called the Baylor Survey Grounds) cover 243,000 acres of the Bay. An additional 110,000 acres outside the public grounds are privately leased for oyster cultivation (Insley, 1987). Clams are found in 20,000 or 30,000 acres of the Baylor Survey Grounds and in an additional 60,000 acres of Chesapeake Bay bottom in Virginia (Royal Insley, personal communication, February 1989).

Two major areas in the Mid-Atlantic subregion are not included in this analysis. About 73,000 acres in upper Chesapeake Bay are not classified by the State of Maryland because they are nonproductive. However, State officials believe that these waters would meet the approved standard throughout most of the year. Also not included are about 280,000 acres of Atlantic Ocean waters classified by New Jersey.

Southeast. About 75 percent of shellfishing waters in the Southeast were classified as approved for harvest, 20 percent as prohibited, 3 percent as conditionally approved, and 2 percent as restricted. Albemarle and Pamlico Sounds are the largest systems in the subregion and account for 1.6 million

of the 1.9 million acres of approved waters, much of which is nonproductive. In 1986, North Carolina Department of Natural Resources conducted a study of 657,000 productive acres throughout the State and concluded that 602,000 acres, or 92 percent, were classified as approved.

Conditionally approved waters in North Carolina are classified by the State as either approved or prohibited, and opened or closed under appropriate conditions. Areas classified as prohibited have management plans describing conditions under which waters may be opened. Areas classified as approved do not have management plans but have been closed due to high coliform levels, especially after rainfall.

Classification data for Georgia are for 1988. In 1985, many areas in the State were classified as prohibited because they lacked adequate sanitary surveys. Approximately 100,000 acres in Georgia have not yet been classified and are not included in this analysis. Acreage figures for Georgia estuaries include areas of intertidal marshes as well as open waters. Productive shellfish grounds are found in the marshes and tidal creeks rather than in the open waters.

The only National Estuarine Inventory system classified for shellfish harvest on the East Coast of Florida in 1985 was the Indian River. Florida manages a conditionally approved area in the Indian River on the basis of rainfall *or* salinity. Models show that waters will not meet the 14 MPN fecal coliform standard when salinities fall below 26.3 ppt, even if there is no rain event. The public health significance of this result has not been addressed.

Trends in Classification, 1971-1985

In the time period from 1971 to 1985, major federal and state efforts were directed at improving water quality in estuarine waters. At the same time, there were major population shifts into the coastal zone. Trends in shellfishing water classifications were examined to determine if improving or declining water quality conditions were reflected in the reclassification data. Unfortunately, a trends evaluation is difficult because waters are reclassified for reasons other than water quality. Boundary markers are moved to simplify enforcement. Waters that were not previously surveyed are opened after completion of a sanitary survey, or waters that were monitored under favorable conditions are closed after sampling under worst case conditions. Many remote areas or small creeks were approved for harvest in 1971 even though they had not specifically been surveyed. Furthermore, the actual reason for changing classification is often lost with personnel changes in the state management agencies.

Trends were evaluated by examining differences between the 1971 and 1985 charts of the *National Shellfish Register* series. State shellfish managers were asked to provide a reason for the change in classification and to distinguish changes that resulted from changes in water quality and pollution sources from those that were primarily administrative changes. A summary of changes are shown in Figure 7; those related to changes in water quality changes are listed in Appendix B.

Trends by Subregion

Northeast. About 120,000 acres in the Northeast subregion changed classification between 1971 and 1985. Less than half of these changes, 51,000 acres, could be related to changes in pollution sources or water quality: 24,000 acres were water quality related upgrades; 28,000 acres were water quality related downgrades. Upgrades were primarily a result of abatements in sewage treatment or septic systems, while downgrades were due to increasing coastal populations with increases in shoreline development and boating activities.

In Maine, sand filter septic systems were installed in unsewered areas to provide greater protection to estuarine waters than the existing leach field systems. Maine, with assistance from the U.S. Environmental Protection Agency began a project in 1973 to identify and correct sewage violations affecting shellfish growing waters. The State estimates that improvements made during 1980 and 1981 resulted in a harvest of more than $600,000 of soft shell clams (Maine/New Hampshire Sea Grant College Program and Maine Department of Natural Resources, 1983).

In Massachusetts, major improvements were made in the sewage treatment facilities along the Merrimack River. These improvements allow waters to be classified as restricted rather than prohibited and shellfish to be used for depuration. Clams harvested in northern Massachusetts are depurated at a plant that was built in 1927, suggesting that pollution problems in this area date back to the early part of the century. Increased monitoring was the reason for downgraded classifications along shoreline areas between Boston Harbor and the Merrimack River.

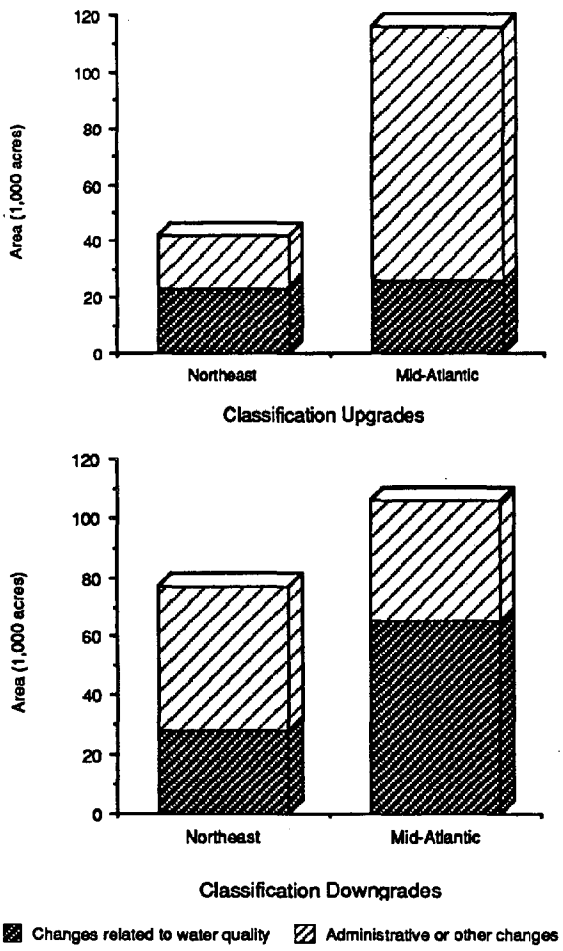


Figure 7. Area of waters reclassified by subregion, 1971-1985

South of Boston, the Massachusetts Division of Marine Fisheries' *Assessment at Mid-Decade* (1985) reported that southern shellfish bed closures increased by 28 percent between 1980 and 1985. These additional closures were mainly in nonurbanized areas without sewage treatment plants or industry. The closures on Cape Cod have increased by 200 percent since 1982. The additional closures are partially a result of increased monitoring efforts and awareness of nonpoint sources. However, real declines in water quality due to development are also implicated. The year-round population on Cape Cod has increased to 170,000, and in summer, the population exceeds 500,000 (Kurtz, 1988).

About 120,000 acres in the Northeast and 220,000 acres in the Mid-Atlantic were reclassified between 1971 and 1985 (Figure 7). Greater than 50 percent of these changes resulted from administrative factors and do not represent any real changes in water quality. Much of the additional closure is a result of increased monitoring, particularly in small creeks and marsh areas that are far from population centers or human sources. Many have questioned the validity of the coliform standard that identifies relatively pristine areas as public health problems, especially areas that were harvested for years without reported problems.

Mid-Atlantic. Changes occurred in about 220,000 acres in the Mid-Atlantic subregion, greater than elsewhere along the East Coast. Again, administrative factors accounted for more than 50 percent of the changes. Of the changes related to water quality, 64,000 acres were downgrades and 26,000 acres were upgrades. As in the Northeast, upgrades were primarily due to improvements in sewage treatment while downgrades were due to coastal development and increased boating activities.

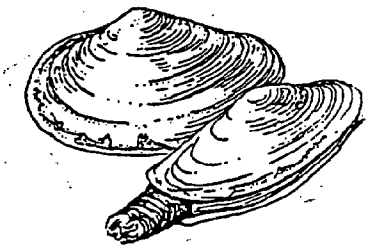
Areas that changed classification because of changes in water quality or pollution sources are identified in Appendix B. Classification upgrades occurred primarily because of improvements in sewage treatment. New Jersey and Maryland constructed regional sewage treatment facilities with open water or offshore outfalls. These replaced septic systems and smaller sewage treatment plants that discharged to estuarine waters.

However, sewage treatment improvements did not always result in upgraded water quality. Some states reported that sewerage actually resulted in additional closures because of the ensuing development. In other cases, existence of other sources, especially nonpoint sources, keep coliform levels above approved water standards. New Jersey hoped to open growing waters in the Navesink and Shrewsbury River after making investments in sewage treatment. Unfortunately, waters could only be upgraded to restricted because of the effect of nonpoint sources.

Southeast. Changes in the Southeast were almost entirely administrative. Major changes have been made in the programs in South Carolina, Georgia, and Florida. In Georgia, most prohibited waters were classified as such because they lacked sanitary surveys from 1971 through 1985. The data presented in the status section is 1988 classification. Some areas still lack sanitary surveys, but these areas are designated as administrative closures.

In North Carolina, an analysis of trends was conducted by the Department of Human Resources (1986). The study showed an overall downward

trend in closures since 1971, but an increase in closures since 1981 as a result of increased coastal development and real declines in water quality. The study was conducted in 46 active growing areas covering about 650,000 acres. Nonproductive areas, including many of the open water areas of Albemarle and Pamlico Sound were not included in the analysis. Since 1971, the area closed to harvest as a result of wastewater treatment plants has declined from 33,000 acres to 12,000 acres. However, closures from urban runoff, septic systems, agricultural runoff and marinas have increased since 1971. Overall, closed areas declined from 70,000 acres to 55,000 acres.



Soft-shell Clam *(Mya arenaria)*

This section summarizes information collected on pollution sources affecting shellfishing waters. Pollution sources that contribute to the permanent or temporary closure of East Coast waters were identified for each harvest-limited area (prohibited, conditionally approved, and restricted) in the Northeast, Mid-Atlantic, and Southeast subregions. These sources are described in Table 3. Pollution sources that discharge directly to estuarine waters are distinguished from upstream sources that affect waters indirectly through tributaries. For example, "upstream sources" describe pollution sources from the Providence River that affect Narragansett Bay. Data were obtained by site visits to shellfish-producing states and from interviews with state personnel, sanitary and shoreline surveys, and other studies.

Concept of Contributing Source

Only those sources that are significant factors in classifying the area were identified. The effect of a pollution source on shellfish growing waters depends on several factors, including the numbers of coliform bacteria discharged by the source to surface waters, the volume of water into which the discharge occurs, and the flushing ability of the receiving waters related to tides and circulation. The effect of a source will depend on the size of the harvest-limited area and the presence of other sources. A marina, which could be significant in a small remote area, might not be identified as a contributing source if it is located in a major urban area. A pollution source may be identified as a contributing factor in a shoreline survey, although the actual contribution of fecal coliform bacteria may be small. In the case of a sewage treatment plant (STP) buffer zone, the shellfish growing area may be closed as a safety zone because of the potential effect of plant failure, rather than the actual contribution of fecal coliform bacteria to the system.

To assess the effect of a pollution source, each source identified as a contributing factor for a classified area is weighted by the acreage of the area. Acreages identified for each source are then summed by estuary to determine total acreage affected by a source. Percent of estuary affected by each source is the ratio of the total affected acreage to the total harvest-limited area of the estuary. Because multiple contributing sources are often identified for a single harvest-limited area, percent contribution for sources in an estuary usually sum to greater than 100 percent.

Table 3. Description of pollution sources

Pollution Source	Description
Sewage Treatment Plants (STPs)	Discharges of inadequately treated effluent from older plants, malfunctioning disinfection systems, or from bypassing of raw sewage through an outfall pipe during overload periods. Buffer zones are established around outfalls to protect public health in case of emergencies.
Combined Sewer Overflows (CSOs)	During periods of heavy rainfall sanitary wastes are combined with stormwater runoff and discharged to the waterbody.
Direct Discharges	Raw sewage discharged from units not connected to collection systems or septic systems.
Industry	Fecal coliform from seafood processors, pulp and paper mills, or from human sewage discharged with industrial wastes. There may be potential hazards from toxics or heavy metals.
Septic Systems	Nonpoint pollution from unsewered areas either from leaching of faulty septic systems or surface runoff from a residential area.
Boating and Shipping Activities	Disposal of raw sewage from boats to coastal waters. Presence of marinas, shipping lanes,or intracoastal waterways.
Urban/Rural Runoff	Storm sewers, drainage ditches, or overland runoff from urban areas containing fecal material from pets, birds, and rodents.
Agricultural Runoff	Runoff from agricultural fields.
Wildlife	Fecal material from waterfowl, rodents, rabbits, beavers, deer, etc.

Contributing pollution sources are shown for Charleston Harbor, for example, in Table 4. Two major harvest-limited areas in the Harbor and the Wando River accounted for 95 percent of the total harvest-limited area of Charleston Harbor. These two areas were affected by sewage treatment plants (STPs) and urban runoff. Septic systems were the likely pollution source in the upper Wando River, contributing to 5 percent of the closures. A 31 acre

marina closure in the Folly River was less than one percent of the Harbor's closed area.

The area in which a pollution source is identified as a contributing cause is summarized by subregion in Figure 8 and by estuary in Appendix C.

Sources of Pollution in the Subregions

Northeast. In the highly developed corridor of the Northeast, shellfish growing waters were affected by a combination of sources associated with urban areas: effluent from sewage treatment plants affected 413,000 acres or 80 percent of Northeast growing areas; and combined sewers and urban runoff, each affected over 275,000 acres (54 percent) of growing waters. The relative impact of each of these sources is extremely difficult to determine, particularly during heavy rainfall events when runoff from pavement combines with overflowing manholes, storm sewers, combined sewers, and treatment plants. In Massachusetts Bay, for example, close to 90 percent of waters were directly affected by sewage treatment plants, combined sewers, and urban runoff from the Boston metropolitan area. The urban areas of Boston, Providence, and the New York City metropolitan area, including coastal Connecticut and Long Island had a major impact on Massachusetts Bay, Narragansett Bay, Long Island Sound, and Raritan Bay.

When functioning properly, sewage treatment plants do not contaminate shellfish growing waters. However, in order to protect public health, state shellfish control agencies classify the areas adjacent to the outfalls of treatment plants as "closed safety zones" or "buffer zones" to protect shellfish beds in the event of a system failure. The safety zones surrounding outfalls are sized according to loadings, hydrographic conditions, and emergency installations and procedures.

Sewage treatment plant failure is a common problem in the heavily populated Northeastern estuaries. In August 1988, malfunctioning treatment plants discharged millions of gallons of raw sewage into Boston Harbor and Quincy Bay, closing productive shellfish beds and posing a major public health risk. About 320 million gallons of sewage was rerouted from the overtaxed Deer Island plant to an antiquated plant at Moon Island. In five days, an estimated 25 million gallons of untreated sewage were discharged into the Harbor, while the remainder was treated only with chlorine before being released from Moon Island z(Armstrong, 1988). Discharges of raw sewage from to the Hudson and East rivers from northern New Jersey and New York City have been estimated at 285 million gallons per day (Conway, 1988).

Many major cities will have to update antiquated sewage treatment plants, collection systems, and combined sanitary and storm sewers in order to solve a major portion of their water quality problems. For example, Boston has begun construction on a $6.1 billion plant that will provide secondary treatment to 480 million gallons of sewage produced daily by 2.5 million people. However, a recent report on Boston Harbor (Caulkins, *et. al.*, 1988) cites combined sewer overflows (CSOs), rather than sewage treatment plants, as a major cause for the closure of shellfish beds in the outer harbor. The report estimates that controlling CSOs alone would result in an additional harvest valued at $315,000 per year at several affected beds.

New Bedford Harbor (in Buzzards Bay) has problems similar to Boston Bay. A recent report on New Bedford (Conservation Law Foundation of New England, 1988) states that sewage pollution rather than polychlorinated biphenyls (PCBs) is keeping vast areas of the Outer Harbor and Clarks Cove closed to shellfishing. New Bedford's sewage now receives only minimal treatment before being dumped in the Outer Harbor. The sewage treat-

Table 4. Sources of pollution in Charleston Harbor

	Classified Area (acres)		Pollution Sources (acres)			
Area Name	Prohibited	Conditional	STP	Septics	Urban Runoff	Boating
Folly River Marina	31					31
Charleston Harbor	17876		17876		17876	
Upper Wando River	1102			1102		
Wando River		5059	5059		5059	
Total	19009	5059	22935	1102	22935	31
% of harvest-limited area			95	5	95	<1

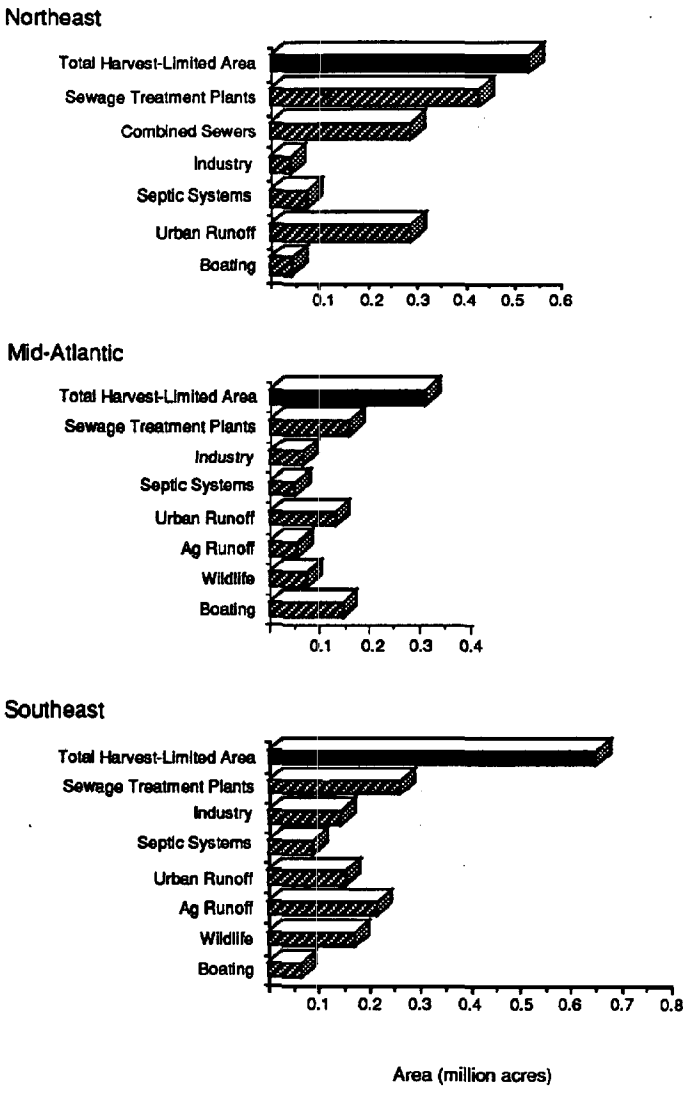


Figure 8. Area affected by pollution sources, by subregion

ment plant has not met the standards for primary treatment on a consistent basis since its construction in 1973. CSOs from New Bedford discharge over 1.5 billion gallons per year into Buzzards Bay. Affected shellfishing waters are estimated to contain over 500,000 bushels of quahogs at a potential annual economic benefit of over $13 million (Conservation Law Foundation of New England, 1988).

In Narragansett Bay, the combination of sewage treatment plants and combined sewers in Providence and Newport affected more than 30,000 acres of shellfishing waters. A conditionally approved area in the lower Providence River was closed to harvest after one-half inch of rain because of the effects of rainfall on combined sewers and treatment plants. Less urban areas of the Bay were affected by septic systems and boating activities.

Sewage treatment plants, combined sewers, and urban runoff affected over 150,000 acres (97 percent of harvest-limited waters) in the Hudson/Raritan complex and 125,000 acres in Long Island Sound (89 percent). The Interstate Sanitation Commission (1987), representing Connecticut, New York, and New Jersey, estimates that 50 million gallons per day (MGD) of raw sewage are released to Hudson/Raritan and Long Island Sound waters. This is an improvement over previous discharges estimated to be as high as 1,066 MGD. In a constant struggle to upgrade facilities, the Commission increased the flow of sewage receiving secondary treatment from 2 MGD in 1936 to 2,411 MGD in 1986. However, two sewage treatment plants in Connecticut and two in New York still operate at primary treatment level and discharge into Long Island Sound. In addition, 14 primary plants in New Jersey discharge into Raritan Bay .

In Great South Bay, urban runoff was identified as the contributing cause in 96 percent of harvest-limited waters, while sewage treatment plants affected only 12 percent of waters. This conclusion is supported by the Suffolk County Executive *Annual Environmental Report* (1987) that cites stormwater runoff as an increasing cause of shellfish bed closures. In addition to bacteria, stormwater runoff transports nutrients to surface waters, potentially resulting in phytoplankton blooms with subsequent depletion of dissolved oxygen.

Outside the major urban areas, smaller communities may be partially or entirely served by septic systems. Similar to sewage treatment plants, septic systems do not contaminate waters when functioning properly. Although septic system failures affecting surface waters can be easily located, subsurface leaching problems are difficult to identify. Because the shellfish classification system is based upon public health, regulators identify septic systems as the cause of contamination, even in cases where there are no obvious malfunctions.

Point sources (sewage treatment plants, combined sewers, direct discharges, or industry) were contributing factors in 85 percent of harvest-limited waters in the Northeast. Areas that were not affected by point sources were found along the coast of Maine, in the small embayments north of Boston Bay, in Cape Cod, Buzzards, Gardiners, and Great South bays, and in the Navesink and Shrewsbury rivers in northern New Jersey.

Nonpoint source problems in Maine were often a result of residential growth in poorly drained coastal regions. All but one estuary was affected by septic effluent. In an attempt to solve the sewage problem, some Maine towns adopted overboard discharge ordinances that may allow development in areas where soils are unsuitable for sub-surface disposal. Solids settle out in a septic tank, the effluent is then pumped through four sand filters, treated with chlorine and discharged into the receiving waters. The systems are not entirely effective due to maintenance problems, lack of chlorination, and pipes that do not extend far enough for dilution and dispersal. Coastal homeowners and developers are faced with a 1992 deadline for the shutdown of any systems polluting shellfish areas.

Massachusetts waters south of Boston Harbor, except for a few urban areas like New Bedford, were affected primarily by nonpoint sources. On Cape Cod, for example, septic systems serving residential areas affected 30 percent of harvest-limited waters, while boating and wildlife contributed to closures of 64 percent and 84 percent, respectively. Wildlife were the likely source of coliform bacteria in many marsh areas closed to harvest. Septic systems, boating, and wildlife were also important factors in shellfish bed closures in Buzzards Bay.

These results are consistent with information reported by the states. A preliminary report on sources of pollution in shellfish growing waters in Massachusetts (Hickey, 1986) found that waters south of Boston were primarily affected by nonpoint sources, except for three urban areas: 1) Taunton River-Mount Hope Bay; 2) New Bedford Harbor-Clarks Cove; and 3) Plymouth Harbor. The Massachusetts study estimates that eighty-nine percent of closed waters on Cape Cod were affected only by nonpoint sources.

Mid-Atlantic. The Mid-Atlantic subregion (New Jersey through Virginia) reflects a contrasting development pattern. Although the Northeast megalopolis now extends in a continuous span of urban area from Maine to Virginia, major cities in this subregion are located inland, with increasing pressures for coastal recreational opportunities and supporting infrastructure crowding the historic coastal activities such as agriculture and fishing. This is reflected in the causes of shellfish bed closures, *i.e.*, only 52 percent attributed to wastewater treatment facilities and 42 percent to urban runoff.

New Jersey built large regional sewage treatment plants that discharge directly into the Atlantic Ocean, reducing the impact of sewage treatment plants in many of the back bays. Although it was once believed that elimination of point sources would open shellfish harvest areas, these waters remain harvest-limited because of urban runoff and boating, both related to coastal recreation. Urban runoff and boating were the major contributing factors in closing waters in Barnegat Bay (100 percent and 79 percent of harvest-limited waters, respectively), Little Egg Harbor (83 percent and 75 percent), Reed/Absecon Bays (89 percent and 52 percent), and Cape May Bays (95 percent and 64 percent).

Boating activity (including marinas and adjacent buffer zones) was a major factor affecting 47 percent of Mid-Atlantic harvest-limited shellfishing waters. The significance of sewage discharge from boats has been controversial nationwide. Boaters generally argue that their discharges are insignificant while federal and state regulators demand stronger controls. Studies in the 1950s and 1960s showed that sampling stations associated with heavy boat

use had higher levels of fecal coliform than stations outside anchorage areas. However, where tidal exchanges were large, no detectable increases in pollution levels attributable to boats were apparent. A positive correlation between the number of boats in Rhodes River Estuary (Chesapeake Bay) and fecal coliform concentrations was reported by Faust and Goff (1978). Boating and marinas were contributing factors in 54 percent of harvest-limited waters in Chesapeake Bay.

To protect public health from the effect of boat wastes, the Interstate Shellfish Sanitation Conference (1985) developed a marina policy that requires states to establish buffer zones around marinas and canals. The area within the marina proper must be classified as prohibited or restricted. An additional closed area beyond the marina may be required. Many shellfish producing states are developing techniques for closing areas based on dilution, dispersion, die-off or residence time, and hydrodynamics, as well as marina design, quality, and usage. Artificial canals, included within this category, are prohibited to shellfish harvest because of limited circulation, high concentrations of boats, and runoff from lawns.

The lower James River, surrounded by urban Norfolk, had the largest harvest-limited area and accounted for much of the urban-related closures in Chesapeake Bay. In the Mid-Atlantic subregion three-fifths of all sewage treatment plant-related closures and one-half of urban runoff closures were in the James River. Many of the closures in the remaining parts of Chesapeake Bay were small areas adjacent to towns and rural communities, rather than major urban areas.

Industries were reported as a contributing cause in closing 65,000 acres (21 percent) in the Mid-Atlantic subregion. Of this, 50,000 acres in the lower James River were closed due to heavy industrial development (in addition to effects from sewage treatment plants and urban runoff). Industrial discharges are of concern to public health officials because of potential effects from toxics and heavy metals. Seafood processing plants, located in coastal areas, may have an impact on the level of fecal coliform bacteria in adjacent waters by discharging processing and sanitary wastes into sewage treatment facilities, or in some cases, directly into receiving waters.

Only 17 percent of shellfish growing waters in the Mid-Atlantic were affected by unsewered developments, either from leaching septic systems or overland runoff. Wildlife was a contributing factor in 23 percent of harvest-limited waters, mainly along the sparsely populated creeks and marshes found in several estuaries in the subregion. Agricultural runoff from crop lands surrounding Delaware and Chesapeake Bays affected 17 percent of harvest-limited waters.

Southeast. Although Southeast estuaries are affected by the coastal location of historic seaports such as Charleston and Savannah, the subregion is the most rural of the East Coast, dependent on agriculture and the timber industry. Municipal wastewater treatment facilities limited the harvest of shellfish in only 44 percent of harvest-limited waters in the more developed estuaries, the lowest percentage of three East Coast subregions, while runoff from urban areas affected only 27 percent.

In the rural estuaries, closures were attributed to agricultural runoff, affecting 37 percent of harvest-limited waters in the subregion. Most of the agricultural activity occurs in North Carolina. In Albemarle and Pamlico Sounds, for example, almost half of the Albemarle-Pamlico Peninsula is farmland (Epperly and Ross, 1986).

The Southeast grew rapidly between 1970 and 1980, due to increases in light industrial activity, pulp and paper production, tourism, and vacation home development. This growth was reflected in the sources of pollution affecting the limitation of harvest; 27 percent by urban runoff, 16 percent due to septic systems, and 12 percent boating. Pulp and paper activities and, to a lesser degree, seafood processing were factors in 24 percent of harvest-limited waters.

Opinions vary on the impact of septic systems in the Southeast. Sanitary surveys of counties in coastal Georgia conclude that despite the unsuitability of soils, septic systems function adequately and do not appear to be contaminating waters (Veazey and Stevens, 1988). Florida, on the other hand, concludes that septic systems are a likely source of contamination because they are often sited in unsuitable soils in low lying coastal areas with high water tables (Florida Department of Natural Resources, 1986). Unsewered areas affected 16 percent of harvest-limited waters in the Southeast, either from leaching septic systems or from surface runoff.

Many areas along the Southeast Coast are undeveloped wetlands, and low-lying creeks. Wildlife associated with these areas affected 29 percent of waters with an additional 10 percent attributed to upstream wildlife sources.

The public health significance of fecal contamination of animal origin is in question. Enteric viruses, the major disease-causing agent when shellfish are harvested from sewage contaminated waters, are human specific and are not believed to be passed from animals to humans. In the Southeast, 230,000 acres of shellfish growing waters are harvest-limited because of wildlife or agricultural runoff, with no human sources. This is one-third of the total harvest limited acreage in the subregion.

In Georgia, low dilution creeks adjacent to upland areas do not meet standards regardless of the land use of the upland area. These areas were once thought to be contaminated from adjacent river systems. Recent data show that the coliform counts in the upper reaches of the creeks are higher than those in the lower reaches, suggesting that runoff from the upland area is the source of contamination. In the undeveloped upland areas, the presumed source of fecal contamination is wildlife (Veazey and Stevens, 1988).

Similarly, a sanitary survey along a sparsely populated stretch of coastal South Carolina concluded that freshwater inflow determined pollution conditions in the area, and that pollution sources in the upper part of the drainage basin had minimal effects on water quality of growing waters (South Carolina Department of Health and Environmental Control, 1988).

The Public Health Debate on Pollution Sources

Contamination of waters with human sewage is a major cause of shellfish-borne diseases. Potential sources of human sewage contamination include sewage treatment plants, combined sewers, direct discharges, septic systems, and boats. However, the public health significance of nonhuman sources of fecal pollution is less certain. Fecal contamination from animal sources may be less of a public health concern because human enteric viruses, the primary etiologic agents in shellfish-borne diseases, are passed specifically between humans. A pathway from humans to animals to shellfish and back to humans has not been demonstrated.

Vast tracts of shellfish beds are closed to shellfish harvest where human sources are virtually nonexistent: 36 percent of harvest-limited waters in the Southeast in 1985; 11 percent in the Gulf; 8 percent in the Mid-Atlantic; and less than one percent in the Northeast. These are areas affected only by wildlife or agricultural runoff. The West Coast is also affected by animal-related closures.

Additional shellfish waters are affected predominantly by urban runoff, containing only animal wastes in most cases. The *Results of the Nationwide Urban Runoff Program* (NURP), produced by EPA (1983), attributes high bacteria levels to heavy loads of animal wastes (primarily pets) in urban runoff. The study also questions the significance of using coliform bacteria as an indicator of sewage contamination when urban runoff is the source.

Scientists and regulators have raised questions regarding the relationships between pollution sources, indicators, and shellfish-borne diseases. There are several efforts underway to provide answers regarding the public health significance of the coliform bacteria indicator, particularly in nonpoint runoff containing fecal matter of nonhuman origin. FDA, in cooperation with the Texas Department of Health, is measuring pathogens in growing areas in Texas affected by wildlife. A NOAA/EPA study (Dufour and White, 1985) uses epidemiological studies to examine relationships between indicators and disease at sites affected by potential point sources (STPs) of human pathogens.

In addition, the *National Collaborative Shellfish Pollution Indicator Study* is a proposed four-year study to evaluate the relationships between indicators and incidence of shellfish-borne disease. Field studies will evaluate proposed alternate indicators of fecal pollution and health risks associated with consumption of shellfish from sites affected by human/animal and only animal sources. Validation of specific indicators in the environment and verification of the public health risk through epidemiological studies will provide a scientific basis to develop meaningful numerical standards on which to base classification of shellfish growing waters.

Concluding Comments

The molluscan shellfish industry is an important economic activity of the East Coast. However, in recent years, harvests have declined dramatically as a result of diminishing shellfish resources and reductions in available harvest grounds. The industry has responded by shifting to new harvesting areas and implementing relay, depuration, and conditionally approved management options for safely harvesting in unapproved waters. Hope for the industry may lie in better management of shellfish resources and in developing new indicators that are better determinants of risk of shellfish-borne disease.

In 1985, 6.6 million acres (82 percent) of East Coast waters were approved for harvest. However, close to 50 percent of this area is nonproductive. Many areas meeting approved standards have extreme salinities or depths, conditions that are unsuitable for shellfish. Of the 1.5 million acres of harvest-limited waters, 34,000 acres were harvested for depuration and 163,000 acres were harvested under conditionally approved management plans. Additional areas were available for relaying. These approaches are costly and place additional burdens on the state shellfish control agency and the industry.

Over the past 15 years, the East Coast shellfish industry experienced a severe decline in shellfish available for harvest, with a related reduction in landings. This loss is a result of overharvesting, shellfish mortality from shellfish diseases and predation, and increased closures of harvesting areas due to pollution. Although the industry is inclined to blame harvesting losses on increased closures, reduced fecundity, increased mortality, and overharvesting are more influential in the decline. In the oyster grounds of the Mid-Atlantic, including Delaware and Chesapeake Bays, the diseases MSX and dermo have devastated the resource. In Maine, and more recently North and South Carolina, closures due to paralytic or neurotoxic shellfish poisoning caused additional closures beyond those experienced due to pollution. Harvest for clams has shifted to the Indian River in Florida, due partially to new Florida programs that allow for relay and depuration. Harvest of oysters has moved to the Gulf Coast, particularly Louisiana.

A trends analysis of changes in classification from 1971 to 1985 was limited because many areas were reclassified as a result of administrative factors, particulary increased monitoring. Overall, water quality improvement efforts over the past 20 years produced only modest results. About 23,000 acres in the Northeast and 26,000 acres in the Mid-Atlantic were upgraded in classification as a result of improved water quality. Many of these upgrades were to conditionally approved or restricted. Although point source discharges were reduced, nonpoint sources prevented many areas from achieving approved standards.

Pollution sources affecting shellfishing waters varied by subregion. Most shellfishing waters in the Northeast that did not meet approved standards were affected by a combination of pollution sources from urban areas, including sewage treatment plants (a contributing factor in 80 percent of all Northeast closures), combined sewers (54 percent), and urban runoff (54 percent). In the less urbanized Northeast estuaries of Maine and southern Massachusetts, nonpoint sources, including runoff from unsewered areas and leaching septic systems, contributed to closures. The influence of urban areas declines in the Mid-Atlantic and Southeast regions, where coastal developments are smaller and often related to recreation. For example, boating activities had greater impacts, affecting 47 percent of harvest-limited waters in the Mid-Atlantic. Wildlife contributed to closures in the less developed estuaries, especially in the coastal marshes in the Southeast (29 percent of Southeast harvest-limited areas). Septic systems affected about 15 percent of harvest-limited waters in each of the three regions. Agricultural runoff was a factor in 36 percent of closures in the Southeast and 17 percent in the Mid-Atlantic, mainly from croplands surrounding Pamlico and Albemarle Sounds, and Chesapeake and Delaware Bays.

The public health significance of animal sources of fecal coliform bacteria, including urban and agricultural runoff and wildlife, has been questioned by scientists and regulators. Evidence suggests that human enteric viruses are not passed from animals to humans through shellfish. Shellfish harvesting areas affected only by agricultural runoff or wildlife accounted for 36 percent of harvest-limited waters in the Southeast and 8 percent of the Mid-Atlantic. Urban runoff affected 38 percent of harvest-limited waters along the East Coast and is the major pollution source in urban or suburban areas where sewage treatment plant discharges have been cleaned up or eliminated.

Additional research is required to resolve the public health questions. Several studies to investigate the relationships between indicators and shellfish-borne diseases are in progress or in planning

stages. Development of a new indicator system may open for harvest waters that are not affected by human sources. FDA, in cooperation with the Texas Department of Health, is measuring pathogens in growing areas in Texas affected by domestic animals and wildlife. A NOAA/EPA epidemiological study is currently examining indicators and incidences of disease at sites affected by sewage treatment plants (human point sources) and will be expanded to include a wildlife site (nonhuman nonpoint source). A proposed four year National Collaborative Shellfish Pollution Indicator Study will examine several sites nationwide affected by human and nonhuman, point and nonpoint sources. Validating relationships between indicators and disease through epidemiological studies will provide a scientific basis for developing meaningful numerical standards for classified shellfish harvesting waters.

The Quality of Shellfish Growing Waters series provides regulators and managers with information on estuarine water quality and other issues related to harvest of molluscan shellfish. The series will be completed this year with an assessment of West Coast shellfishing waters. This work provides a sound basis for future data collection efforts, beginning with the *1990 National Shellfish Register of Classified Estuarine Waters.*

References

Anderson, I. C., M. Rhodes, H. Kator. 1979. "Sublethal stress in *Escherichia coli* : a function of salinity." *Applied and Environmental Microbiology.* 38(6): 1147-1152.

Armstrong, D. "Hub sewage overflow threatens beaches, closes shellfish beds." *The Boston Herald.* August 10, 1988.

Busby, D. 1986. *An overview of the Indian River clamming industry and the Indian River Lagoon.* Florida Sea Grant Technical Paper 44. Gainesville, FL. pp. 1-5.

Calabrese, A., E. Gould, and F. Thurberg. 1982. "Effects of toxic metals in marine animals of the New York Bight: some laboratory observations." In *Ecological stress and the New York Bight: science and management.* G. Mayer (ed). Estuarine Research Federation. Columbia, SC. pp 281-197.

Calabrese, A. and H. C. Davis. 1976. "Effects of 'soft' detergents on embryos and larvae of the American oyster *(Crassostrea virginica)." Proceedings National Shellfisheries Association.* 57:11-16.

Caulkins, P., C. Binkley, C. Ruf, and C. Miller. 1988. "The role of economic benefits analysis in funding marine combined sewer overflow projects — case study of Boston Harbor." *Journal Water Pollution Control Federation.* 60(7): 1275-1280.

Connecticut Department of Environmental Protection. 1984. *A marine resources management plan for the State of Connecticut.* Hartford, CT. pp 182-185.

Conway, C. "The trashing of the Jersey shore." The *Philadelphia Inquirer.* July 31, 1988. pp 28-35.

Conservation Law Foundation of New England. 1988. *Lost harvest. Sewage, shellfish and economic losses in the New Bedford area.* Boston, MA. 27 pp.

Davis, H.C. 1961. "Effects of some pesticides on eggs and larvae of oysters *(Crassostrea virginica)* and clams *(Venus mercenaria)". Commercial Fisheries Review.* 23(12):8-23.

Dufour, A.P. and H. White. 1985. *Health effects associated with shellfish consumption.* NOAA/EPA IAG RW13931029. Rockville, MD. 29 pp.

Environmental Protection Agency, Water Planning Division. 1983. *Results of the nationwide urban runoff program. Executive summary.* Washington, D.C. 21 pp.

Epperly, S. P. and S. W. Ross. 1986. *Characterization of the North Carolina Pamlico-Albemarle estuarine complex.* NOAA Technical Memorandum NMFS-SEFC-175.

Faust, M.A. and N.M. Goff. 1978. "Sources of bacterial pollution in an estuary." *Coastal Zone '78. Proceedings of the symposium on technical, environmental, socioeconomic, and regulatory aspects of coastal zone management.* pp 819-839.

Figley, W., B. Pyle, and B. Halgren. 1979. " Socioeconomic impacts." in *Oxygen depletion and associated benthic mortalities in New York Bight.* R. L. Swanson and C. J. Sinderman (eds). NOAA Professional Paper 11. Washington, D.C. pp 315-322.

Florida Department of Natural Resources, Shellfish Environmental Assessment Section. 1986. *Comprehensive shellfish harvesting area survey. Duval County, Florida.* Tallahassee, FL.

Food and Drug Administration, Shellfish Sanitation Branch, and National Oceanic and Atmospheric Administration, Strategic Assessment Branch and National Marine Fisheries Service. 1985. *1985 national shellfish register of classified estuarine waters.* Rockville, MD. 19 pp.

Food and Drug Administration, Shellfish Sanitation Branch. 1971. *1971 national shellfish register of classified estuarine waters.* Northeast Technical Services Unit. Davisville, RI. 19 pp.

Grosslein, M. D. and T. R. Azarovitz. 1982. *Fish distribution.* MESA New York Bight Atlas Monograph 15. New York Sea Grant Institute. Albany, NY. 182 pp.

Hargis, W.J. Jr. and D.S. Haven. 1988. "Rehabilitation of the troubled oyster industry of the lower Chesapeake Bay." *Journal of Shellfish Research.* 7(2): 271-279.

Hickey, M.J. 1986. *Preliminary report. Estimated acreage of closed shellfish waters as a result of point and nonpoint pollution sources.* Massachusetts Division of Marine Fisheries. Sandwich, MA.

Insley, R. C. 1987. "An overview of the Virginia oyster fishery management plan." *Proceedings of the 1987 Interstate Seafood Seminar.* Virginia Department of Health, Division of Shellfish Sanitation. Richmond, VA. pp 209-235.

Interstate Sanitation Commission. 1987. *1986 annual report..* New York, NY. 70 pp.

Interstate Sanitation Commission. 1988. *1987 annual report..* New York, NY. 80 pp.

Interstate Shellfish Sanitation Conference. 1985. *Marina policy.* Texas Department of Health, Shellfish Sanitation Division. Austin, TX. 1 pp.

Interstate Shellfish Sanitation Conference. 1986. *National Shellfish Sanitation Program manual of operations. Part 1. Sanitation of shellfish growing areas.* FDA. Washington, DC. 135 pp.

Kassner, J. 1988. "The consequence of baymen: The hard clam *(Mercenaria mercenaria* Linne) management situation in Great South Bay, New York." *Journal of Shellfish Research.* 7(2): 289-293.

Kurtz, H. 1988. "Cape Cod building ban suggested." *The Washington Post.* June 2.

Lewis, E.J. 1987. "Dermo *(Perkinsus marinus),* SSO *(Haplosporidium costale),* and MSX *(Haplosporidium nelsoni)* - current impact on shellfish." *Proceedings of the 1987 Interstate Seafood Conference.* Virginia Department of Health, Division of Shellfish Sanitation. Richmond, VA. pp 113-127.

Maine/New Hampshire Sea Grant College Program and Maine Department of Marine Resources. 1983. *Increasing clam harvests in Maine: a practical guide.* University of Maine, Orono. 60 pp.

Massachusetts Division of Marine Fisheries. 1985. *Assessment at mid-decade.* Boston, MA. 31 pp.

Morse, D.L., *et. al.* 1986. "Widespread outbreaks of clam- and oyster-associated gastroenteritis. Role of Norwalk virus." *New England Journal of Medicine.* 314(11): 678-681.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 1987. *Fisheries of the United States, 1986.* Washington, D.C.

National Oceanic and Atmospheric Administration, Strategic Assessment Branch. 1985a. *National estuarine inventory data atlas. Volume 1: physical and hydrologic characteristics.* Rockville, MD. 103 pp.

National Oceanic and Atmospheric Administration, Strategic Assessment Branch. 1985b. *National estuarine inventory data atlas. Volume 2: land use characteristics.* Rockville, MD. 40 pp.

North Carolina Department of Human Resources, Shellfish Sanitation Program. 1988. *Trends and causes of closures of shellfish waters in North Carolina.* Morehead City, NC. 11 pp.

Renzoni, A. 1973. " Influence of crude oil derivatives and dispersants on larvae". *Marine Pollution Bulletin.* 4:9-13.

Richards, G. P. 1985. "Outbreaks of shellfish-associated enteric virus illness in the United States: requisite for development of viral guidelines". *Journal of Food Protection.* 48(9): 815-823.

Rhodes, M. W., I. C. Anderson, and H. I. Kator. 1983. "In situ development of sublethal stress in *Escherichia coli* : effects on enumeration." *Applied and Environmental Microbiology.* 45(6): 1870-1876.

Shumway, S. E., *et. al.* 1988. "Paralytic shellfish poisoning in Maine: monitoring a monster." *Red Tide Newsletter.* 1(2):8.

South Carolina Department of Health and Environmental Control. 1988. *Statewide water quality assessment FY 1986-1987.* Columbia, SC pp. 69-94.

Stamman, E., D.A. Segar, and P.G. Davis. 1987. *A preliminary epidemiological assessment of the potential for diarrhetic shellfish poisoning in the Northeast United States.* NOAA Technical Memorandum NOS OMA 34. Rockville, MD. 18 pp.

Suffolk County Executive. 1987. *Annual environmental report - 1987.* Suffolk County, NY. 75 pp.

Suffolk County Planning Department. 1987. *Strategies and recommendations for revitalizing the hard clam fisheries in Suffolk County New York. 1987.* Hauppauge, NY. pp 2.

Tester, P.A. and P.K. Fowler. in preparation. "Effects of toxic dinoflagellate *Ptychodiscus brevis* on contamination, toxicity, and depuration of *Crassostrea virginica* and *Mercenaria mercenaria.* "

Thurberg, F.P., Calabrese, A. and Dawson, M.A. 1974. "Effects of silver on oxygen consumption of bivalves at various salinities." *Pollution and Physiology of Marine Organisms.* New York, NY. pp 67-78.

U.S. General Accounting Office. Resources, Community, and Economic Development Division. 1988. *Seafood safety. Seriousness of problems and efforts to protect consumers.* GAO/RCED-88-135. Washington, DC. 77 pp.

Veazey, J.E. and S.A. Stevens. 1988. *A description of biological and physical parameters affecting the sanitary quality of Georgia's shellfish resources: a sanitary survey.* Georgia Department of Natural Resources, Coastal Resources Division. Brunswick, GA.

Appendices

A. Personnal Communications

B. Waters Reclassified as a Result of Water Quality Changes

C. Sources of Pollution in East Coast Shellfishing Waters

Appendix A. Personnal Communications

Ammen, S. Division of Law Enforcement, Office of Environmental Affairs. Boston, MA.

Anderson, W. South Carolina Wildlife and Marine Resources. Charleston, SC.

Backer, T. Connecticut Coastal Fishermen's Association. Norwalk, CT.

Baker, J. Tallmadge Brothers Oyster Company. New Bern, NC.

Barker, S. Maine Department of Marine Resources. Augusta, ME.

Bartsch, E. Division of Water Programs, Virginia Department of Health. Richmond, VA.

Beck, A. USEPA/ERLN. Narragansett, RI.

Benton, R. Chief of Shellfish Sanitation Program, North Carolina Department of Human Resources. Morehead City, NC.

Berrigan, M. Environmental Administrator. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Bickings, H. Petersons Packing Company. Port Norris, NJ.

Bigford, T. Chief of Habitat Conservation Branch, North East Region, National Marine Fisheries. Gloucester, MA.

Bloom, H. Tallmadge Brothers, Inc. Norwalk, CT.

Branche, J. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Brands, R. Investigating Branch, DHHS/PHS/FDA. Baltimore, MD.

Butterfield, M. Chief of Law Enforcement, New Hampshire Fish and Game Department. Concord, NH.

Cabelli, V. Microbiology Department, University of Rhode Island. Kingston, RI.

Carpenter, A.C. Potomac River Fisheries Commission. Colonial Beach, VA.

Chadwick, D. Division of Marine Fisheries. Newburyport, MA.

Chesebrough, D. New Hampshire Water Supply and Pollution Commission. Concord, NH.

Coffin, G. Maine Department of Marine Resources. Augusta, ME.

Coker, M. Environmental Quality Manager, Shellfish and Recreational Waters Division, South Carolina Department of Health and Environmental Control. Columbia, SC.

Colby, S. Massachusetts Executive Office of Environmental Affairs. Boston, MA.

Cole, R. Division of Fish and Wildlife, Department of Natural Resource and Environmental Control. Dover, DE.

Critchlow, G. Chief of Bureau of Shellfisheries, New Jersey Division of Fish, Game, and Wildlife. Trenton, NJ.

Croonenburgh, R. Virginia Department of Health. Richmond, VA.

Davidson, M. Executive Director of South Carolina Sea Grant Consortium. Charleston, SC.

Davies, D. Suffolk County Planning Department. Hauppauge, NY.

Davies, T. Shellfish Section, South East Region, Department of Environmental Quality. Lakeville, MA.

Davis, R. DHHS/PHS/FDA. Philadelphia, PA.

Delaney, J. Chief of Lawrence Experimental Agency, DEQE. Lawrence, MA.

Delaney, R. Massachusetts Office of the Executive. Boston, MA.

deQuillfeldt, C. Bureau of Shellfish, New York State Department of Environmental Conservation. Stony Brook, NY.

DiStefano, P. Standards and Certification, Maryland Department of the Environment. Baltimore, MD.

Dowgert, M. State Programs Branch, DHHS/PHS/FDA. Boston, MA.

Elsele, W. New Jersey Department of Environmental Protection. Leeds Point, NJ.

Ellingsen, Col. D.N. Director, Division of Law Enforcement, Florida Department of Natural Resources. Tallahassee, FL.

Fair, J. Marine Fisheries Resources. Boston, MA.

Ford, S. Rutgers University. Bivalve, NJ.

Foster, W. Maine Department of Marine Resources. Augusta, ME.

Fowler, P. Shellfish Sanitation Program, North Carolina Department of Human Resources. Morehead City, NC.

Futch, C.R. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Gaines, J. Food and Drug Administration. Northeast Technical Services Unit. Davisville, RI.

Garreis, M.J. Standards and Certification, Maryland Department of the Environment. Baltimore, MD.

Gilbert, G. Shellfish Sanitation Program, North Carolina Department of Human Resources. Morehead City, NC.

Grant, G. New Jersey Fisheries Development Commission. Trenton, NJ.

Harden, B. Acting Chief of Division of Food Control, Maryland Department of Health and Mental Hygiene. Baltimore, MD.

Haskins, H. Rutgers University. Bivalve, NJ.

Hastback, W. New York State Department of Environmental Conservation, Bureau of Shellfisheries. Stony Brook, NY.

Heil, D.C. Environmental Administrator, Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Hickey, J.M. Massachusetts Division of Marine Fisheries. Sandwich, MA.

Hope, J. Bureau of Shellfish Sanitation, Virginia State Department of Health. Richmond, VA.

Howell, R. Director of Sanitary Engineering, Bureau of Environmental Health, Department of Health and Social Service. Dover, DE.

Hughes, W. Atlantic Coast Shellfish Council. Atlantic Highlands, NJ.

Hurst, J. Bureau of Marine Sciences, Maine Department of Marine Resources. West Boothbay Harbor, ME.

Ianucci, W. Rhode Island Department of Health. Providence, RI.

Insley, R.C. Virginia Marine Resources Commission. Newport News, VA.

Jenson, P. Fisheries Administration, Maryland Department of Natural Resources. Annapolis, MD.

Joseph, J. National Marine Fisheries Service. Charleston, SC.

Karp, C. Project Manager of Narragansett Bay Project. Providence, RI.

Kassner, J. Town of Brookhaven, Division of Environmental Protection. Patchogue, NY.

Kipp, K. EPA Region 1. Boston, MA.

Krantz, G. Director, Oxford Laboratory. Maryland Department of Natural Resources. Oxford, MD.

Leedy, M. General Manager of United Shellfish Company, Inc. Grasonville, MD

Leland, R. Industry Area. McClellanville, SC.

Levere, A. Department of Environmental Protection, Natural Resource Center. Hartford, CT.

Lynch, T. Division of Fish and Wildlife, Department of Environmental Management. Wickford, RI.

MacFarlane, S. Orleans Shellfish Department. Orleans, MA.

Mallowes, H. H.L. Mallows and Son. Marion, MA.

Malmberg, V. Chief of Bureau of Laboratory Services, Department of Health and Welfare. Concord, NH.

Markland, R. Assistant Commissioner, Law Enforcement, Virginia Marine Resource Commission. Newport News, VA.

Marshall, M. Division of Marine Fisheries. Morehead City, NC.

McCoy, E. Law Enforcement, Division of Marine Fisheries. Morehead City, NC.

McGroary, A. Director of Division of Law Enforcement Affairs. Boston, MA.

Migliori, J. Department of Environmental Management, Division of Water Resources. Providence, RI.

Miller, D. Bureau of Environmental Health, Department of Health and Social Service. Dover, DE.

Moore, K. Environmental Quality Manager, Shellfish and Recreational Waters Division, Department of Health and Environmental Control. Columbia, SC.

Morgan, C. Morgan Seafood. Weems, VA.

Morgan, W. Morgan Seafood. Weems, VA.

Morris, D. Bureau of Marine Resource Regulation and Development, Department of Natural Resources. Tallahassee, FL.

Mulnick, J. DHHS/PHS/FDA. Brooklyn, NY.

Munden, F. Division of Marine Fisheries. Morehead City, NC.

Nelson, J. Fisherman's Harvest. Anahuac, TX.

Newell, C. Great Eastern Mussel Farm, Tenants Harbor, ME.

Nunally, A.L. South Carolina Department of Health and Environmental Control. Sullivans Island, SC.

Nuzzi, R. Suffolk County Department of Health. Hauppauge, NY.

Peachey, R. Bureau of Shellfish Sanitation, Virginia State Department of Health. Richmond, VA.

Pecora, R. Maryland Department of the Environment. Baltimore, MD.

Pruell, R. USEPA. Narragansett, RI.

Raiche, P. Bureau of Environmental Health, State Department of Health and Welfare. Concord, NH.

Relyea, F. Frank M. Fowlers and Sons. Bayville, NY.

Richards, G. National Marine Fisheries Service. Charleston, SC.

Richardson, K. University of Rhode Island. Narragansett, RI.

Ridley, N. Director of Division of Food and Drugs, Massachusetts Department of Public Health, State Lab Institute. Jamaica Plains, MA.

Sample, J. National Marine Fisheries Service. Charleston, SC.

Sansbury, C. South Carolina Department of Health and Environmental Control. Columbia, SC.

Schneider, J.W. Chief, Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Shute, M. Connecticut State Department of Health Services. Hartford,CT.

Siddall, S. Marine Sciences Research Center, State University of New York. Stony Brook, NY.

Sieling, W. Office of Seafood Marketing, Maryland Department of Agriculture. Annapolis, MD.

Siewicki, T. National Marine Fisheries Service. Charleston, SC.

Silver, K. ARFDD for Intergovernmental affairs, DHHS/PHS/FDA. Brooklyn, NY.

Simns, L. President of Maryland Watermen's Association. Annapolis, MD.

Sisson, R. Division of Fish and Wildlife, Department of Environmental Management. Wickford, RI.

Smith, S. Author. Cape Cod, MA.

Somerset, I. State Programs Branch, DHHS/PHS/FDA. Boston, MA.

Stacy, P. Connecticut Department of Environmental Protection. Hartford, CT.

Stevens, S. Coastal Resources Division, Georgia Department of Natural Resources. Brunswick, GA.

Stokes. A. Waddell Aquaculture Center. Hilton Head, SC.

Taylor, J. Director of Laboratories Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Thieling, D. Marine Resource Division. Charleston, SC.

Travelsted, J. Virginia Marine Resources Commission. Newport News, VA.

Tryon, K. Connecticut Shellfish Company. Branford, CT.

Tucker, J. Director of Laboratories, Lab Division, Connecticut State Department of Health. Hartford, CT.

Van Volkenburgh, P. Chief of Bureau of Shellfish, New York State Department of Environmental Conservation. Stony Brook, NY.

Veazey, J. Coastal Resources Division, Georgia Department of Natural Resources. Brunswick, GA.

Verber, J. FDA Retired. North Kingstown, RI.

Volk, J. Chief of Aquaculture Division , Department of Agriculture. Milford, CT.

West, N. Assistant Professor, Department of Geography and Marine Affairs, University of Rhode Island. Kingston, RI.

Wetherell, R. Food and Drug Administration. Northeast Technical Services Unit. Davisville, RI.

Wienkel, R. Deputy Chief of Marine Law Enforcement Bureau, New Jersey State Police. West Trenton, NJ.

Wiley, C.W. Director, Bureau of Shellfish Sanitation, Virginia State Department of Health. Richmond, VA.

Wilkinson, E. Enforcement Division, Rhode Island Department of the Environment. Providence, RI.

Winters, H. Maine Department of Marine Resources. Augusta, ME.

Wolf, G. Consumer Health Services, New Jersey Department of Health. Trenton, NJ.

Wright, M. Bureau of Shellfish Sanitation, Virginia State Department of Health. Richmond, VA.

Appendix B. Waters Reclassified as a Result of Water Quality Changes

Estuary /Area	Classification 1971	1985	Acres Changed losses	gains	Reason for Change
Northeast					
Passamaquoddy Bay					
Rogers I	a	p	221		development
Carryingplace Cv	a	p	69		development, malfunction of local sources
Pleasant Pt	a	p	22		new STP
Cutler	p	a		28	abatement of septics
Englishman Bay					
Howard Cove	a	p	257		development
Machias R	p	c		142	new STP
Holmes Bay	p	c		222	abatement of herring plant
Narraguagus R					
Pigeon Hill	c	a		48	abatement of local sources
Little Moose I	p	a		38	abatement of local sources
Blue Hill Bay					
East Blue Hill	a	p	48		shore development
Blue Hill Harbor	p	a		510	STP removed local sources
Penobscot Bay					
Center Harbor	c	p	33		shore development
Stonington	a	p	143		shore development
South Deer I	a	p	77		shore development
Fort Point Cove	p	r		1488	sewage abatement in Penobscot R
Sears I	p	c		1492	sewage abatement in Penobscot R
Searsport Harbor	r	p	179		expanded STP
Penobscot R, E shore	p	r		890	sewage abatement in Penobscot R
Penobscot R, E shore	a	p	1762		local development
Belfast Bay	r	a		1566	municipal abatement
Belfast Bay	r	p	4794		shore development
Frohock Brook	a	p	35		shore development
Isleboro	a	c	58		shore development
Harborside	a	p	64		shore development
Billings Cove	a	p	23		shore development
Deer I - NW Hrb	p	a		20	abatement of local sources
Vinalhaven	a	p	28		shore development
Pulpit Harbor	c	p	123		local sources
Camden	p	a		280	STP replaced local sources
Rockport Harbor	a	p	2542		shore development
Tenants Harbor	p	c		220	abatement of septics
Long Cove	a	p	28		shore development
Sprucehead I	p	a		77	abatement of septics
Harrington Cove	p	a		36	abatement of septics
Muscongus Bay					
St. George R	p	r		504	STP Improvements
Bird Point	a	p	92		malfunctioning septic at single home
Hupper I	a	p	265		collection system, no treatment
Friendship	c	p		313	collection system, no treatment
Friendship	a	p	110		malfunctioning septic at single home
Muscongus Sound	c	a		79	abatement of septics
New Harbor	a	p	33		shore development
New Harbor	a	c	10		shore development

Abbreviations: a, approved; p, prohibited; c, conditional; r, restricted.

Continued...

(Continued)

Estuary /Area	Classification 1971	1985	Acres Changed losses	gains	Reason for Change
Sheepscot Bay					
Wiscasset	c	p	120		new STP buffer zone
Wiscasset	c	a		148	new STP
Back R	p	a		2850	abatement of septics
Montsweag Bay	p	a		2400	abatement of septics
Damariscotta	p	a		34	abatement of septics
Pemaquid R	p	c		386	abatement of septics
Rutherford I	p	c		107	abatement of septics & str. pipes
Rutherford I	a	p	153		development
Linekin Neck	a	p	71		shore development
Southport I	p	c		48	abatement of straight pipes
Hodgdon Cove	c	p	24		shore development
Sheepscot R	p	c		60	abatement of straight pipes
Casco Bay					
Sabino	a	p	64		shore development
Winnegance	a	p	170		shore development
Harbor I	p	a		15	abatement of septics & str. pipes
Gurnet Str/Doughty Cv	p	c		79	abatement of septics & str. pipes
Gurnet Str/Doughty Cv	a	c	115		shore development
Buttermilk Cove	a	p	66		shore development
Lowell Cove	c	p	122		shore development
Bailey I	a	p	155		shore development
S Harpswell	p	a		534	abatement of septics & str. pipes
Basin Cove	c	a		168	abatement of septics & str. pipes
Stover Cove	a	p	18		shore development
Middle Bay	a	p	51		shore development
Barnes Pt	p	a		18	abatement of septics
Mere Pt	a	p	31		shore development
Bunganuc Ldg	p	r		158	abatement of straight pipes
Harraseeket R	p	c		714	new STP
Cousins R	p	r		107	abatement of septics
Chandler Cove	a	p	143		shore development
Sunset Point	p	a		21	abatement of septics
Wildwood Pk/Waites Lg	p	r		162	new STP
Wildwood Pk/Waites Lg	p	c		339	new STP
Wildwood Pk/Waites Lg	p	a		300	new STP
Portland	p	r		533	new STP
Portland	a	p	1665		development
Saco Bay					
Nonesuch R	p	r		794	STP
Goosefare Brook	a	p	457		STP buffer
Saco R	p	r		585	STP
Little R	p	a		194	area became sewered
Cape Porpoise	p	a		81	area became sewered
Mousam R	p	c		357	STP
Mousam R	a	c	161		STP buffer
Little R	a	p	20		shore development
Ogunquit R	p	c		71	STP
Great Bay					
Spruce Cr	p	r		219	improved septics
Spinney Cr	p	r		108	improved septics
Merrimack R					
Marshes	p	r		216	upgraded STPs; improved WQ
Massachusetts Bay					
Gloucester Hbr	a	p	1097		more fish processing
Nanatasket Bch	p	a		251	STP upgrade

Abbreviations: a, approved; p, prohibited; c, conditional; r, restricted.

Continued...

(Continued)

Estuary /Area	Classification 1971	1985	Acres Changed losses	gains	Reason for Change
Cape Cod Bay					
Wellfleet	a	p	53		more boats
Cape Cod Canal	a	p	74		Maritime Academy STP
Cape Cod Canal	a	p	62		Maritime Academy STP
Plymouth Hbr	a	p	985		increased boating, STP overload
Kingston Bay	a	p	530		more boating, declining WQ
Green Hbr R	a	p	118		development, new STP outfall
Buzzards Bay					
W Falmouth/Megansett	p	a		1500	recovery from oil spill
Cataumet	a	c	36		expanding marina
Back R	a	p	74		development
Buttermilk Bay	a	p	538		development
Wareham	p	a		118	area became sewered
Sippican Hbr	a	c	166		increased boating
Sippican Hbr	p	a		24	mercury problem cleaned up
Smiths Neck	a	p	707		STP outfall
Cuttyhunk Pond	a	p	33		increase in houses on septics
Cuttyhunk Pond	a	c	71		increased boating
Narragansett Bay					
Mount Hope Bay	a	p	2400		declining WQ, STP problems
Jamestown	p	c		10	eliminated sewer outfall
Jamestown	c	p	191		new STP buffer!
Kickamuit River	a	p	66		decline in water quality
Mt Hope Bay/Sakonnet	a	p	849		decline in water quality
Wickford	a	c	218		increased boating activities
Wickford	c	p	150		increased boating activities
Pearson Yacht STP	a	p	19		new STP buffer
Long Island Sound					
Old Saybrook	p	c		197	corrected septics
open areas	c	a		42	corrected septics
Haycock Pt	p	a		30	removed outfall
Southport	c	p		66	decline in water quality
Westcott Cove	p	a		1500	upgraded lift stns
Cove Hbr	p	c		310	improved STPs
Cockenoe Hbr	p	c		285	upgraded pump stns
Mt Sinai	a	p	16		increased boats
Mt Sinai	a	c	63		increased boats
Huntington Hbr	a	p	303		deteriorating STP & admin
Plum Point	a	p	38		new STP buffer
Gardiners Bay					
Hashamomuck	a	c	152		possibly due to development
Hudson/Raritan					
Sandy Hook	a	r	2880		declining water quality
Sandy Hook	r	p	551		declining water quality
Navesink/Shrewsbury	a	r	1017		declining water quality
Total Northeast Region			28145	24026	
Mid-Atlantic					
Barnegat Bay					
Metedeconk R	a	c	292		shoreline development, nonpoint sources
Seaweed Point	a	c	158		shoreline development, nonpoint sources
Lavallette	a	c	268		shoreline development, nonpoint sources
Goodluck Point	a	c	2700		shoreline development, nonpoint sources
Holly Park	a	c	722		shoreline development, nonpoint sources
Waretown	p	c		479	regional STP eliminated local discharge
Barnegat Beach	p	c		778	regional STP eliminated local discharge

Abbreviations: a, approved; p, prohibited; c, conditional; r, restricted.

Continued...

(Continued)

Estuary /Area	Classification 1971	1985	Acres Changed losses	gains	Reason for Change
Little Egg Harbor					
Manahawkin Bay	p	c		156	regional STP eliminated local discharge
Horse Point	p	c		152	regional STP eliminated local discharge
Little Egg Harbor	p	c		1263	regional STP eliminated local discharge
Reed/Absecon Bays					
Reed Bay	p,c	a		1365	regional STP eliminated local discharge
Absecon Bay	p	c		1026	regional STP eliminated local discharge
Lakes Bay	p,r	c		1816	regional STP eliminated local discharge
Great Egg Hbr Inlet	p,c	a		1921	regional STP eliminated local discharge
Scull Bay	p	a		637	regional STP eliminated local discharge
Steelman Bay	c	a		72	regional STP eliminated local discharge
Ocean City Shoreline	p	c		224	regional STP eliminated local discharge
Great Egg Harbor Bay	c	a		1396	regional STP eliminated local discharge
Great Egg Harbor Bay	p	a		255	regional STP eliminated local discharge
Great Egg Harbor R	c	p	477		increased flow through STP
Mill Thorofare	a	p	395		increased flow through STP
Ingram Thoro/So. Chan	a	p	523		increased flow through STP
Great Sound	p	c		100	regional STP eliminated local discharge
Nummy Island	a	p	256		increased flow through STP
Jenkins Sound	a	p	659		increased flow through STP
Delaware Bay					
Bidwell Cr	c	p	224		nonpoint sources
Dennis Cr	a	p	530		nonpoint sources
Thompson Bch	a	c	2917		septics exposed by storm
Dividing/Fishing Cr	a	c	846		nonpoint sources
Back/Cedar Cr	a	c	2782		nonpoint sources
Delaware Inland Bays					
Indian R Bay	a	c	2499		seafood processing wastes, now ag runoff
Indian R Inlet	a	p	191		increased boating and shipping
Rehoboth Bay	p	c		569	area became sewered
Chesapeake Bay					
Manokin R	a	p	100		sanitary violations
Little Choptank R	p	a	5060		correct septics, eliminate livestock
Choptank R	p	a		4239	improved STP and sewers, eliminated violations
Tar Creek	a	p	120		failing septics, some administrative
Upper Harris Cr	a	p	477		septics, domestic animals
Cummings Cr	a	p	385		septics
St. Michaels	a	p	96		new STP (Talbot County #2)
Spencer/Little Neck Crs	p	a		63	sewers replaced septics
Hunting Cr	a	p	266		failing septics
Kent Narrows	a	c	193		development, more septics
Marshy Cr	a	c	289		development, more septics
Kent Island	a	p	19		new STP outfall
Cox Cr	p	a		140	regional STP eliminated local STP
Little Cr	a	p	35		failing septics, direct discharges
Upper Chester R	p	a		859	improved STP
Corsica R	p	a		107	improved STP
Rock Hall	p	a		584	regional STP replaced STP, septics
Magothy R	a	p	1624		development, urban runoff
Tydings on the Bay	a	p	32		new STP (Broadneck)
Severn R	p	a		2853	improved STP, pumping stations
Fishing Cr	a	p	244		Coast Guard STP (eliminated after 1985)
Rhode R	a	p	396		sanitary violations, marinas
Duvall Cr	a	p	94		failing septics, boats
Selby Bay	a	p	151		failing septics, boats
Franklin Manor	a	p	84		new STP (Broadwater)
Island Cr	a	p	169		failing septics
Battle Cr	a	p	240		failing septics
Town Cr	a	p	61		marinas, septics
Pine Hill Run	a	p	317		moved STP outfall offshore
St. Jerome Cr, No. Br	a	p	120		nonpoint sources

Abbreviations: a, approved; p, prohibited; c, conditional; r, restricted.

Continued...

(Continued)

Estuary /Area	Classification 1971	1985	Acres Changed losses	gains	Reason for Change
Herring Bay	p	a		1752	STP improvements, elim septic failures
Upper Miles R	a	p	1264		sanitary violations
Wye Island	a	p	1227		domestic animal runoff
Potomac R					
Whites Neck Cr	a	p	215		failing septics, ag runoff, dom. animals
St. Patrick Cr	a	p	214		failing septics, urban runoff
Cuckold Cr	a	p	60		buffer for new STP (Swan Point)
Breton Bay	a	p	638		failing septics
Herring Cr	a	p	266		failing septics and domestic animals
Piney Point Bch	a	p	200		STP
St. Marys R	p	a		1283	regional STP replaced STP & septics
Locust Grove Cove	a	p	11		nonpoint sources
Schoolhouse Br	a	p	28		animal pollution
Schoolhouse Br	a	c	133		water quality decline
Coan Cr	a	c	507		water quality decline
Coan Cr	a	c	130		water quality decline
Coan Cr	a	c	224		water quality decline
Jackson Cr	a	c	200		water quality decline
Davis Cr	a	c	43		seasonal boating activity
Timberneck Cr	p	c		74	water quality improvements
Lower York R	a	p	2811		buffer zone for new STP
Lower York R	a	c	138		water quality decline
Ocean View	a	c	9955		water quality decline
Long & Grunland Crs	a	p	129		water quality decline
Long & Grunland Crs	a	c	96		water quality decline
Back R SW Br	a	c	296		water quality decline
Back R SW Br	p	c		122	water quality improvements
Back R SW Br	a	c	10893		water quality decline
Upper Warwick R	p	c		160	water quality improvements
Lower Warwick R	p	c		133	water quality improvements
Pagan R	p	c		631	water quality improvements
Pagan R	a	c	192		water quality decline
Nansemond R	a	c	617		water quality decline
Nansemond R	a	c	1522		water quality decline
Hampton Roads	a	p	548		buffer zone for new STP
Broad Bay	a	c	715		rapid development
Broad Bay	a	p	30		rapid development
Lynnhaven Bay	a	p	625		rapid development
Lynnhaven Bay	a	c	1364		rapid development
Tangier Isl	a	p	1098		buffer zone for new STP
Orancock Cr	p	c		459	by-passing STP
Orancock Cr	a	c	1397		by-passing STP
Orancock Cr	a	c	53		boating activity
Total Mid-Atlantic Region			64850	25668	

Abbreviations: a, approved; p, prohibited; c, conditional; r, restricted.

Appendix C. Sources of Pollution in East Coast Shellfishing Waters

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	Upstream STP	Upstream Ur Runoff
ME	Passamaquoddy Bay	Carryingplace Cv	69							69						
		Pembroke	127							127						
		Dennys R	48							48						
		St. Croix R	4203			4203										
		Bar Harbor	482							482						
		Pleasant Pt	22			22										
		Eastport	275							275						
		Reynolds Pt	26									26				
		North Lubec	415							415						
		Crane Mill Brook		13								13				
		Broad Cv	303							303						
		Lubec Neck	156							156						
	Total Passamaquoddy Bay		**6126**	**13**		**4225**				**1875**		**39**				
	Percent of total					**69**				**31**		**1**				
	Englishman Bay	Holmes Bay		222		222										
		Huntley Creek	41			41										
		Randall Flats			804					804						
		Howard Cove	257							257						
		Machias R	1699			1699										
	Total Englishman Bay		**1997**	**222**	**804**	**1962**				**1061**						
	Percent of total					**65**				**35**						
	Narraguagus Bay	Jonesport	349							349						
		Pidgeon Hill Bay		41						41						
		Beals Island	115							115						
		Narraguagus R	826							826						
	Total Narraguagus Bay		**1290**	**41**						**1331**						
	Percent of total									**100**						
	Blue Hill Bay	Macon R	2606			2606				2606						
		Blue Hill Harbor	222			222										
		Bass Harbor	20		704					724						
		McHeard Cv	48							48						
	Total Blue Hill Bay		**2896**		**704**	**2828**				**3378**						
	Percent of total					**79**				**94**						
	Penobscot Bay	Ducktrap Harbor	60							60						
		Rockland Harbor	2275						2275							
		Duck Harbor		209						209						
		North Haven	825							825						
		Camden Harbor	164			164										
		Deer Island Thorofare	311							311						
		Gilkey Harbor		796						796						
		Deer Isle	80							80						
		Passagassawakeag R			199	199				199						
		Belfast Bay	4794			4794				4794						
		Sears Island		1492		1492				1492						
		Searsport	360			360				360						
		Cape Jellison	4570							4570						
		Northern Bay			722	722										
		Ft. Point Cove			1448	1448				1448						
		Penobscot R	5702			5702				5702						
		Gilkey Harbor		202						202						
		Rockport Harbor	4942							4942						
		Castine	2216			2216										
		Harborside	179							179						
		South Brooksville	13							13						
		Harbor Island		306						306						
		Billings Cv	23							23						
		Center Harbor	101							101						
		Morse Cv			890	890				890						
		Wadsworth Cv		158						158						
		Stonington	268							268						
		Pulpit Harbor	123					123		123						
		Inner Harbor	77							77						
		Sabbathday Harbor	265							265						
	Total Penobscot Bay		**27349**	**3163**	**3259**	**17987**		**123**	**2275**	**28394**						
	Percent of total					**53**		**<1**	**7**	**84**						
	Muscongus Bay	Port Clyde	324							324						
		Bird Cv	92							92						
		Below Waldoboro			71	71										
		Hoffse Point		432		432										
		Waldoboro	71			71										
		Thomaston			504	504										
		Lower St.George R		1568		1568										
		Upper St.George R	248			248										
		Lawrey	15							15						
		Round Pond (closed)	3							3						
		Round Pond		99						99						
		Pleasant Pt	38							38						
		Hatchet Cv	716							716						
	Total Muscongus Bay		**1507**	**2099**	**575**	**2994**				**1287**						
	Percent of total					**69**				**31**						

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	Upstream STP	Upstream Ur Runoff
	Sheepscot Bay	Rutherford Island	620							620						
		Christmas Cove		107						107						
		Hockamock Bay	2740			2740				2740						
		Macmahan Island	112							112						
		Wiscasset	592			592				592						
		Five Islands	128							128						
		Damariscotta	438							438						
		Back R	250						250							
		Hogdon Cv		58						58						
		Pig Cove		48		48										
		Boothbay Harbor	4362			4362										
		Little R	222							222						
		Linekin Bay		1448						1448						
		East Boothbay	110							110						
		Georgetown	15							15						
		Merrymeeting Bay	13326			13326			13326							
		Kennebec R			1933	1933			1933							
		Cozy Harbor	28							28						
		Pemaquid Harbor	173											173		
		Pemaquid		386						386						
		Hendricks		263						263						
	Total Sheepscot Bay		**23116**	**2310**	**1933**	**23081**			**15509**	**7267**				**173**		
	Percent of total					**84**			**57**	**27**				**<1**		
	Casco Bay	Harpswell Harbor	18							18						
		Prince Pt	14							14						
		South Harpswell	293							293						
		Orrs Island	1558							1558						
		Chandler Cv	143			143										
		Buttermilk Cove	66							66						
		Gurnet		194						194						
		Middle Ground		201						201						
		Macworth			533	533								533		
		Portland	8912			8912								8912		
		Card Cv	314							314						
		Cundys Harbor	105							105						
		Sebasco Harbor	102							102						
		West Pt	31							31						
		Weston Point			38	38										
		Harrascket R		1090		1090										
		Bungaruc			158											
		Sabine	64							64						
		Broad Cove			73	73										
		Falmouth Foreside		339		339										
		Cousins R			107	107				107						
		Merpoint Bay		449						449						
		Mere Pt Neck	31							31						
		Royal R	304			304										
		Winnegance Bay	280							280						
		Wildwood park			89	89					89					
		Hartswell Neck	51													
	Total Casco Bay		**12236**	**2273**	**998**	**11628**				**3827**	**89**			**9445**		
	Percent of total					**75**				**25**	**1**			**61**		
	Saco Bay	Saco R	1073			1073										
		The Pool			585	585										
		Scarborough R	27						27							
		Nonesuch R			794				794							
		Goosefare brook	481			481										
	Total Saco Bay		**1581**		**1379**	**1554**			**794**							
	Percent of total					**53**			**27**							
ME	Great Bay	Portsmouth	1365			1365										
		Crocketts Neck			219	219										
		Salmon R/Portsmouth B	993			993				993						
		Eagle Point	66			66										
		Spruce Cr			221	221				221						
		Spinney Cr			108					108						
NH	Great Bay	Squamscott/Lamprey Rs	475			475										
		Portsmouth	1520			760		760								
		Piscataqua R	3297			3297						3297	3297			
		Weeks Bay	955							955	955					
	Total Great Bay		**8671**		**548**	**7396**		**760**		**2277**	**955**	**3297**	**3297**			
	Percent of total					**80**		**8**		**25**	**10**	**36**	**36**			
MA	Merrimack R	Merrimack R	2243			2243									2243	2243
		Plum Island R			216				216	216	216		216	216		
	Total Merrimack R		**2243**		**216**	**2243**			**216**	**216**	**216**		**216**	**216**	**2243**	**2243**
	Percent of total					**91**			**9**	**9**	**9**		**9**	**9**	**91**	**91**

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	Upstream STP	Upstream Ur Runoff
MA	Massachusetts Bay	Town Head	36				36				36					
		Gloucester Hbr	1527			1527	1527		1527		1527					
		Blynman Canal			65					65	65			65		
		Manchester Bay	226			226					226					
		Salem Sound Shore	146								146					
		Danvers R	1286			1286	1286				1286			1286		
		Winter I	24								24					
		Salem Harbor	954			954					954			954		
		No. Shore Marblehead	40								40					
		Marblehead Hbr	504								504			504		
		Phillips Beach	40								40					
		Nahant Beach	271								271			271		
		Cohasset Marsh	115							115	115		115			
		Cohasset Cove	140							140	140			140		
		Scituate Hbr	258							258	258			258		
	Boston Bay	Hingham Harbor			472								472			
		White Head Flats			185									185		
		Fox Pt	61			61			61		61			61		
		Quincy Bay Marsh			43	43			43		43					
		Planters Hill			148									148		
		Hole Pt Reach			196	196			196		196			196		
		Rock Island Cv			243	243			243		243					
		North Weymouth			182	182			182		182					
		Weymouth	33			33			33		33					
		Quincy Pt	150			150			150		150			150		
		Kings Cv	28			28			28		28			28		
		Sea Cr			285	285			285		285					
		Weymouth R			68	68					68			68		
		Nantasket roads	570											570		
		South Channel	289			289				289				289		
		Allerton	98								98					
		Winthrop	212			212	212		212		212					
		Squantum			281	281			218		281					
		Governors Island			327	327			327		327			327		
		Dear Island	39			39			39		39					
		Quincy			318	318			318		318			318		
		Squaw/Chapel Rocks	46			46			46		46					
		Surfside			130	130			130		130					
		Nut Island	33			33			33		33					
		Weymouth Great Hill			106	106			106		106			106		
		Hull			25	25			25	25	25			25		
		Stodders Neck	30											30		
		East Weymouth	20			20					20			20		
		Hingham Bay			130									130		
		Weir R	82								82		82			
		Dorchester Yacht Club	56			56			56		56			56		
		Dorchester Bay			87	87			87		87					
		Quincy Bay	135			135			135		135					
		Orient Heights	476			476	476		476		476			476		
		Pleasure Bay			149	149			149		149			149		
		East/SouthBoston	2393			2393			2393		2393			2393		
		Columbia Point	215			215			215		215			215		
		Old Harbor			23	23			23		23			23		
		Pt Shirley			67	67			67		67			67		
		Dorothy Cove	43			43	43									
		Broad Sound	6132			6132	6132				6132					
		Seaplane Basin			108					108	108					
		Pines R			110					110	110					
		Chelsea Point			70	70			70		70			70		
		Winthrop Beach	34			34			34		34			34		
		Snake Island			100	100			100		100			100		
		Neponset R	358			358			358		358			358		
	Total Boston Bay		*11533*		*3853*	*13453*	*6803*		*6838*	*532*	*13519*		*554*	*6592*		
	Percent of total					*87*	*45*		*44*	*3*	*88*		*4*	*43*		
	Total Massachusetts Bay		**17100**		**3918**	**17446**	**9676**		**8365**	**1110**	**19115**		**669**	**10070**		
	Percent of total					**83**	**46**		**40**	**5**	**91**		**3**	**48**		
	Cape Cod Bay	Plymouth Harbor	1964										1964	1964		
		Provincetown Marsh	45										45			
		Maraspin Cr	41			41							41	41		
		Duxbury	13										13			
		Kingston Bay	685					685		685		685	685			
		Green Harbor	45					45	45				45			
		Wellfleet Harbor	53					53		53						
		Provincetown (closed)	61					61		61						
		Provincetown Harbor		170				170		170						
		Cape Cod Canal	163			163								163		
		Sandwich Harbor	32							32						
		Scorton Harbor		43								43	43			
		Cordage	58					58			58					
	Total Cape Cod Bay		**3160**	**213**		**204**		**1072**	**45**	**1001**	**58**	**728**	**2836**	**2168**		
	Percent of total					**6**		**32**	**1**	**30**	**2**	**22**	**84**	**64**		

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	Upstream STP	Upstream Ur Runoff
	Buzzards Bay	Red Brook Harbor		36						36				36		
		Quisset Harbor		36						36				36		
		South Dartmouth	33					33								
		West Cuttyhunk Pond	33					33		33				33		
		East Cuttyhunk Pond		71				71		71				71		
		Mattapoisett Hbr	28											28		
		New Bedford	7661			7661			7661							
		Great Harbor	83			83				83				83		
		Sippican Harbor		166										166		
		Hammett Cv	10							10						
		Back R	74						74				74	74		
		Cape Cod Canal	62					62								
		Buttermilk Bay	533					533	533	533		533	533			
		Salters/Mishaum Pts	707			707										
		Hiller Cv	18							18		18				
		Eel Pond	17							17				17		
	Total Buzzards Bay		**9259**	**309**		**8451**		**732**	**8268**	**837**		**551**	**607**	**544**		
	Percent of total					**88**		**8**	**86**	**9**		**6**	**6**	**6**		
MA	Narragansett Bay	Mount Hope Bay/Taunton R	5624			5624	5624	5624		5624						
		Palmer/Runnins R	117					117		117			117			
RI	Narragansett Bay	The Glen	20			20										
		Dutch Harbor		10										10		
		Taylor Point	191			191										
		McCorrie Point	26							26						
		Hundred Acre Cove		465							465					465
		Jamestown		8										8		
		Pearson Yachts STP	19			19										
		Bull Pt	97					97		97				97		
		Davisville Pier	71											71		
		Quonset	712			712										
		Fishing Cove		218										218		
		Wickford	227							227				227		
		Bissel Cv	80							80			80			
		Providence R	5618			5618	5618		5618							5618
		Upper Bay		10100											10100	10100
		Barrington R	632			632			632					632		
		Mt Hope Bay	6846			6846	6846									6846
		the Cove	166							166						
		Bristol Yacht Club		115										115		
		Bristol Harbor	566			566								566		566
		Potter Cv		102										102		
		Greenwich Bay		148										148		
		Apponeag Cove	115							115	115			115		
		Warwick Cv	120							120	120			120		
		Greenwich Cv	291			291					291			291		
		Gould Island	33													
		Sakonnet Harbor		13										13		
		Newport	2344			2344	2344				2344			2344		
		Melville	376											376		
		South Ferry	52			52										
	Total Narragansett Bay		**24343**	**11179**		**22915**	**20432**	**5938**	**6250**	**6572**	**3335**		**197**	**5453**	**10100**	**23595**
	Percent of total					**65**	**58**	**16**	**18**	**19**	**9**		**1**	**15**	**28**	**66**

State	Estuary	Area	Classification (acres)			Pollution Sources (acres)										Upstream	
			Prohibited	Conditional	Restricted	STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	STP	Ur Runoff
CT	Connecticut R	Connecticut R	4951												4951	
	Long Island Sound	Connecticut R delta	1876												1876	
		Indiantown	300												300	
		Plum Bank Bch		197											197	
		Clinton	337								337		337	337		
		Stonington & Pawtucket	2086			2086							2086			
		West Cv	39											39		
		Mystic Harbor	1049			1049									1049	
		New Haven Buffer Zone	142			142					142					
		Connecticut R Delta	319												319	
		Upper Thames R	1597			1597									1597	
		Watts Island	154										154			
		Smith's Cv	48								48			48		
		Keeny Cv	38								38					
		Upper Niantic R	196								196		196			
		Lower Niantic R	15							15						
		Niantic Bay entrance	18							18				18		
		Jordan Cv	121							121						
		Lower Thames R	6574			6574	6574								6574	6574
		Mumford Cv	305			305										
		Bartlett Reef	444			444										
		Townshend Ledge	2343			2343					2343					
		Seaview	2							2						
		Webster	2							2						
		Bride Outfall	39			39										
		Patchogue	133							133				133		
		Sachem and West Rs	1862								1862		1862	1862		
		Stone Cr		1189				1189		1189		1189				
		Branford Harbor	1939			1939								1939		
		New Haven Harbor	13313			13313	13313				13313					
		Housatonic R	1897			1897					1897					
		the Gulf	920								920			920		
		Penfield Reef	3111			3111					3111					
		Payes Reach	5131			5131					5131					
		Bridgeport	12249			12249	12249				12249					
		Southport	66							66				66		
		Holly Pond	196										196			
		Stamford Harbor	3178			3178					3178					
		Westcott Cv	269								269			269		
		Cv Harbor		310									310	310		
		the gut	168			168					168			168		
		Fivemile R	121							121						
		Sheffield Harbor		1301		1301								1301		
		Norwalk Harbor	1589			1589	1589				1589			1589		
		Canfield Island	55										55			
		Cockenoe hbr		2678		2678	2678				2678			2678		
		Saugatuck Harbor	613			613	613							613		
		Sherwood mill Pond	100							100				100		
		Wilson Cv	75							75				75		
		Greewich Pt	8029			8029					8029					
NY	Long Island Sound	Port Jefferson Harbor	854			854				854	854		854	854		
		Wading Pond	50										50			
		Steers Canal	10							10	10					
		Cold Spring Harbor	215			215					215		215	215		
		Smithtown Bay	1300			1300										
		Frost Cr	2								2					
		Stony Brook	9							9			9			
		Crab Meadow Cr	4							4	4		4			
		Nissequogue R	555							555	555		555			
		Huntington Harbor	393			393				393	393			393		
		Plum Pt	38			38								38		
		Oyster Bay Harbor	375			375					375			375		
		the Cove	88									88				
		Mill Neck Cr	304							304	304					
		Mattituck	170							170	170			170		
		Stony Brook Harbor	10										10			
		Inlet Point	300			300					300					
		Mt Sinai	16	63						16	16			63		
		effluent lagoon	8						8							
		Northport Harbor	339			339					339					
		Northport basin	27						27					27		
		Western Sound	50877			50877	50877				50877					
		Fishers Island	910			910										
		Centerport Harbor	49										49			
	Total Long Island Sound		134912	5738		125376	87893	1189	35	4157	111912	1277	6942	14600	16853	6574
	Percent of total					89	62	1	<1	3	80	1	5	10	12	5

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Ur/Suburb Rural	Ag Runoff	Wildlife	Boating	Upstream STP	Ur Runoff
NY	Gardiners Bay	Turtle Cv	13							13						
		Mill Cr	28										28			
		Birch Cr	46										46			
		South Jamesport	10								10					
		East Cr	15								15		15	15		
		Fanning Pt	180			180										
		Miamogue Lgn	7										7			
		Chases Cr	40							40	40					
		Sag Harbor	155			155										
		NorthSea	12											12		
		New Suffolk	10							10	10			10		
		Stirling Basin	52			52				52	52			52		
		Flanders Bay	1395							1395	1395		1395			
		Hashamomuck Pond	170							170	170			170		
		Lake Montauk	150	31						31				150		
		Simmons Pt	5										5			
	Total Gardiners Bay		**2288**	**31**		**387**				**1711**	**1692**		**1498**	**409**		
	Percent of total					**17**				**74**	**73**		**65**	**18**		
NY	Great South Bay	Moriches Bay	3945							3945	3945		3945			
		Bellport Bay	495										495			
		Islip	1163								1163					
		Atlantique		10										10		
		Babylon	3155								3155					
		Patchogue Bay	3235			3235				3235	3235					
		Davis Park		120										120		
		Brookhaven	547							547	547		547			
		Cherry Cove		150										150		
		Shinnecock Bay	254							254	254			254		
		Quantuck	183								183					
		South Oyster Bay		220						220				220		
		Lower South Oyster Bay	2990								2990					
		Short Beach Island		47							47					
		East Bay	10611								10611					
	Total Great South Bay		**26578**	**547**		**3235**				**8201**	**26130**		**4987**	**754**		
	Percent of total					**12**				**30**	**96**		**18**	**3**		
NY	Hudson R/ Raritan Bay	Lower Bay	51125			51125	51125				51125					
		Hudson R	33488			33488	33488				33488					
		New York Hbr	14698			14698	14698				14698					
		Western Long Island Sound	7483			7483	7483				7483					
NJ	Hudson R/ Raritan Bay	Parkers	106								106			106		
		Oceanport Cr	60								60			60		
		Blackberry Cr	51								51			51		
		Town Neck Cr	28								28			28		
		Silver Cr	41								41			41		
		Hudson R	2966			2966	2966									
		Hudson R	1325			1325	1325									
		Sandy Hook Bay			15904	15904	15904									
		Raritan/Newark Bays	29284			29284	29284									
		Raritan R	2207			2207	2207									
		Red Bank	385			385					385					
		Shrewsbury/Navesink R			4282						4282	4282				
		McClees Bay	20			20					20					
		Oyster Bay	28								28					
		Gallee	23								23	23				
		Racoon Island	84								84					
		Long Branch Marina	6											6		
		Pleasure Bay	252								252			252		
		Union/Belvedere Beaches	551			551	551									
	Total Hudson/Raritan		**144211**		**20186**	**139436**	**139031**				**112154**	**4305**		**544**		
	Percent of total					**97**	**97**				**68**	**3**		**<1**		
	Total Northeast subregion		**450913**	**28138**	**34520**	**413168**	**277032**	**9714**	**41757**	**74502**	**275656**	**10197**	**21247**	**44376**	**29206**	**32412**
	Percent of total					**80**	**54**	**2**	**8**	**15**	**54**	**2**	**4**	**9**	**6**	**6**

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur runoff	Wildlife
NJ	Barnegat Bay	Manasquan R	1350							1350			1350			
		Metedeconk R	1593							1593			1593			
		Bay Head Harbor		292						292			292			
		Mantoloking		24						24			24			
		Swan Point	22							22			22			
		Island Beach	1513							1513			1513			
		Middle Sedge		268						268			268			
		Kettle Cr	851							851			851			
		Seaweed Point		158						158			158			
		Seaweed Point Marina	7										7			
		Havens Point Marina	51										51			
		Havens Cove	7										7			
		Sloops Point	5										5			
		Goose Cr Marina	342							342			342			
		Toms R	1442							1442			1442			
		Bay Seaside Park		2700						2700						
		Bay, Holly Park	639							639			639			
		Cedar Cr	489							489			489			
		Bay:Cedar Beach		722						722						
		Sunrise Beach Marina	94							94			94			
		Stouts Cr	84							84			84			
		Forked River to Waretown	441							441			441			
		Off Sands Point Harbor		479					479	479			479			
		Barnegat Light	59							59			59			
		Marsh	2							2			2			
		Silver Bay	904							904			904			
		Barnegat Marina	5										5			
		Loveladies Marina	2							2			2			
		Bay:Loveladies		115						115			115			
		Loveladies Harbor	30							30			30			
		West Long Beach Island		55						55			55			
		Kinseys Pond	4							4						
		Bay:Harvey Cedars		46						46			46			
		Harvey Cr	3							3						
		Harvey Pond	8							8						
		Bay:long Beach	2							2						
		Pebble Beach	167						167	167			167			
		Barnegat Beach		778					778	778			778			
		Bay:Surf City		397						397			397			
		Surf City Lagoon	4										4			
		Manahawkin Bay	38							38			38			
		Cedar Cr	60							60			60			
	Total Barnegat Bay		**10218**	**6034**					**1424**	**16173**			**12913**			
	Percent of total								**9**	**100**			**79**			
	Little Egg Harbor	Wells Island	24							24			24			
		Big Thorofare	190						190			190	190			
		Holgate		30						30			30			
		Holgate Marina	16										16			
		Holgate Lagoon	7										7			
		Landing Cr		75								75				
		Oyster Cr	25						25			25	25			
		Mott Cr	76						76			76	76			
		Nacote Cr	112						112			112	112			
		Upper Mullica R	750						750	750		750				
		Lower Mullica R		201											201	201
		Gravelling Pt	2										2			
		Gravelling Lgn	3										3			
		Manahawkin Bay	206							206			206			
		Thorofare Isl		156						156			156			
		Ship Bottom Lgn	4										4			
		Long Beach	20										20			
		Bay:Long Beach		1313						1313			1313			
		Horse Pt		152					152	152			152			
		Westecunk Cr	138						138	138			138			
		Parkers Run	77						77	77		77	77			
		Thompson Cr	12						12	12		12	12			
		Gaunt Pt	51							51			51			
		Tuckerton Cr	79							79			79			79
		Thorofare Pt		134						134			134			
		Bass R	224							224		224	224			
		Ballanger Cr	10							10		10				
		Long Beach Lgn	3										3			
		Bay: Beach Haven		287						287			287			
		Beach Haven Coast Guard	6										6			
		Judies Cr		2						2		2				
		Winter Cr	3							3		3				
		Ballanger Marsh		25						25		25				
		Roundabout Cr		48						48		48				
	Total Little Egg Harbor		**2038**	**2423**					**1532**	**3721**		**1629**	**3347**		**201**	**280**
	Percent of total								**34**	**83**		**37**	**75**		**5**	**6**

State Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur runoff	Wildlife
Reed/Absecon Bays	W Atlantic City	140							140						
	Upper Great Egg Hbr R		20								20				
	Lakes Bay		1816						1816						
	Great Island	28							28						
	Baremore Quarters	13							13			13			
	Bonita Tideway		188						188						
	Great Egg Coast Guard	9										9			
	Ocean City		84						84						
	Tuckahoe R/Ludlam Cr	101									101				
	Peck Bay Marina		36									36			
	Duck Thorofare			64								64			
	Great/Beach Thorofare	856							856			856			
	Ventnor City	676							676			676			
	Margate City	856							856			856			
	Great Egg Harbor R		734								734				
	Tuckahoe R	232									232				
	Great Egg Harbor R	1776			1776				1776		1776				
	Lakes Cr/English Cr Landing	306							306		306				
	Jeffers Landing		140						140		140				
	Somers Marsh	99							99		99				
	Absecon Cr	51							51			51			
	Absecon Shoreline	145							145		145	145			
	Absecon Bay		1388						1388		1388	1388			
	Rum Point	112							112			112			
	Mankiller Bay	909							909			909			
	Clam/Duck Thorofare	568							568			568			
	Bay Peck Beach	334							334			334			
	Patcong Cr	104							104		104				
	Canal	10									10				
	Somers Cove	66									66				
	Somers Pt		61						61			61			
	Rainbow Channel		140						140			140			
	Bass Harbor	36										36			
	Ship Channel	8							8			8			
	Ocean City Lgn	2										2			
Total Reed Absecon Bays		7437	4607	64	1776				10798		5121	6284			
Percent of total					15				89		42	52			
Cape May Bay	Halfmile Point Marsh		100					100			100				
	Gravelly Run	237							237		237				
	Jenkins Sound	1992			1992				1992		1992				
	Ingram Thorofare	300			300				300			300			
	Stone Harbor	1288			1288				1288			1288			
	Reubens Thorofare	288			288						288				
	Upper Thorofare	184							184			184			
	Middle Thorofare			403					403			403			
	Crook Horn Cr	335							335		335	335			
	Strathmere	25						25							
	Whale Cr		260					260	260						
	Whale Beach	10						10	10						
	Ludlam Thorofare	513			513				513			513			
	Ware Thorofare	178			178				178			178			
	Townsend Sound	395			395				395			395			
	Townsend Channel	35							35			35			
	Stites Sound	237						237	237			237			
	Cape May Harbor	71							71			71			
	Cape May Canal	270			270				270		270	270			
	Cape May			375					375			375			
	Taylor Cr			125					125		125				
	Jones Cr	130			130						130				
	Richardson Sound	727			727				727		727				
	Wildwood Crest	720			720				720			720			
	Grassy Sound	1672			1672				1672			1672			
Total Cape May Bay		9607	360	903	8473			632	10327		4204	6975			
Percent of total					78			6	95		39	64			

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	Upstream STP	Sources Ur runoff	Wildlife
NJ	Delaware Bay	Jacobs Cr	25									25				
		Cohansey R	1920			1920			1920			1920				
		Cedar Cr		298					298			298				
		Lower Nantuxent Cr		20					20			20				
		Upper Nantuxent Cr	200						200			200				
		Newport Neck	12						12			12				
		Bidwell Cr	224						244			224				
		Cape May	11842			11842										
		Beadon Cove	30									30				
		Fortescue Cr	886						886			886	886			
		Fortescue	141						141			141	141			
		Dividing Cr		581					581			581				
		Oranoakan Cr		174								174				
		Maurice R	2654			2654			2654			2654				
		Maurice R Cove		2917					2917			2917		2917		
		Riggins Ditch	316			316						316				
		West Cr	133								133	133				
		Roaring Ditch	153								153	153				
		Dennis Cr	816								816	816		816		
		Dias Cr	51						51			51				
		Goshen Cr	15								15	15				
		Cr North/Arnold Point	20									20				
		Stow Cr	510									510				
		Bay Side	10									10				
		Bacons Neck	10									10				
		Cohansey Cr	15			15				15		15				
		Cohansey Cove	326							326		326	326			
		Dyer Cove	449						449			449				
		Sow and Pigs Cr	6									6				
		Back Cr		683					683			683				
		Nantuxent Cove		1601					1601			1601				
		Arnold Point Shoal	5661									5661		5661	5661	5661
DE	Delaware Bay	Cedar Bch	1163						1163		1163	1163				
		Mispillion R	449						449		449	449				
		Murderkill R	306			306					306	306				
		Murderkill Neck	4131			4131					4131	4131				
		St Jones R	1061			1061					1061	1061				
		Leipsic R	2070									2070				
		Mahon R	408									408				
		Simons R	1153									1153				
		Broadkill	683			683					683	683				
		Lewes Rehoboth Canal	357			357										
		Lewes Bch/Breakwater Hbr	3213			3213		3213			3213	3213				
	Total Delaware Bay		**41419**	**6274**		**26498**		**3213**	**14269**	**341**	**12123**	**35494**	**1353**	**9394**	**5661**	**5661**
	Percent of total					**56**		**7**	**30**	**1**	**25**	**74**	**3**	**20**	**12**	**12**
DE	Delaware Inland Bays	Indian River Inlet	191										191			
		Rehoboth Bay (closed)	237			237										
		Rehoboth Bay		507		507										
		Lewes Rehoboth Canal	357										357			
		White Oak	127			127										
		White Oak Cr		189		189										
		Rehoboth Bald Eagle	475			475										
		Indian River (closed)	1833								1833					
		Indian River		2499							2499					
		Salt Pond	163								163					
		White Creek (closed)	165										165			
		White Cr		153									153			
	Total Delaware Inland Bays		**3549**	**3348**		**1535**					**4495**		**866**			
	Percent of total					**22**					**65**		**13**			

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur runoff	Wildlife
MD	Chesapeake Bay	Marumsco Cr	255								255	255				
		Williams Pt	1449									1449				
		Chesapeake Bay at Pine Hill	317			317										
		Nanticoke R	3324									3324				
		Wicomico R	1321									1321				
		Monie Cr	90									90				
		Little Monie Cr	70									70				
		Back Cr	87						87				87			
		St. Peters Cr	184						184							
		Manokin R	100							100		100				
		Hall Cr	55			55										
		Daugherty Cr Canal	59									59				
		Little Annemessex R	960			960		960					960			
		St.Jerome Cr/NorthProng	120								120					
		Pine Hill Run	206			206										
		Cummings Cr	385						385							
		St. Michaels Harbor	79							79			79		79	
		Miles R @ Parrot Pt	96			96										
		Upper Patuxent R	3728							3728		3728			3728	
		Mill Cr	18						18				18			
		Indian Cr	148							148	148	148				
		Trent Hall	151							151	151	151				
		Washington & Persimmon Crs	196							196	196	196				
		Battle Cr	380							380	380	380				
		Island Cr	194							194	194	194				
		Town Cr	61						61				61			
		Solomon Island Crs	640						640	640			640			
		Choptank R @Bow Knee Pt	247								247	247				
		Corsica R	505			505										
		Queenstown Cr	319			319										
		Grays Inn Cr	535			535										
		Magothy R	1397							1397						
		Forked Cr	76							76						
		Deep Cr	76							76						
		Cornfield Cr	94						94							
		Herring Bay	773			773										
		Bch to Plum Pt	1346			1346										
		Tilghmam Island	1282						1282							
		Baileys Neck	6			6					6	6				
		Tar Cr	120					120	120				120			
		Town Cr	115			115				115			115			
		La Trappe Cr	515			515										
		Jenkins Cr	90			90										
		Choptank R /Hambrooks bar	89			89										
		Hudson Cr	312								312	312				
		Fishing & Church Crs	1331								1331	1331				
		Severn R	3714			3714			3714				3714			
		Glebe Bay	255						255	255			255			
		Duvall Cr	94						94				94			
		Fishing Cr	270			270			270				270			
		Selby Bay	170						170				170			
		Ramsay Lake	137						137				137			
		White Marsh/Bear Neck Crs	135			135										
		Fox/Mudy Boathouse Crs	202							202		202				
		Lerch/Smith/South Crs	647						647				647			
		Cadle Cr	59						59				59			
		Parish Cr	125			125							125			
		Franklin Manor	84			84										
		Shipping Cr	90						90							
		Little Cr	35						35				35			
		Kent Island Narrows	339					339		339			339			
		Marshy Cr	326							326						
		Memorial Bridge Sewer	59			59										
		Wye R/Skipton, Pickering Cr	3410								3410	3410				
		Wye R. wharf	7										7			
		Harris Cr/NW	477						477		477					
		Craighill Channel Spoil	77			77										
		Upper Round Bay	1373						1373	1373						
		Mill Cr	269						269							
		Leeds Cr	419						419		419	419				
		Hunting Cr	375								375	375				
		Oak Cr	151									151				
		Miles:Goldsborough/Glebe Cr	1264								1264	1264				
		Tred Avon	1686							1686	1686	1686				
		San Domingo Cr	207						207	207						
		Choptank R @ Cambridge	1706			1706										
		Whitehall Cr	115								115	115				
		Indian Cr	74								74	74				
		Goose Cr	38								38	38				
		Warwick R	255			255										
		Sandy Pt Bridge	1			1										
		Tracy and Rockhold Crs	192						192	192			192			
		Rock Hall Harbor	145							145			145			
		Tavern/Swan Crs	653						653	653			653			
		Whitehall/ Meredith Creeks	317							317			317			
		Pine Hill Run South	41			41										
		Pine Hill Run North	41			41										
		Patapsco R:Bay entrance	5225													5225
		South R	1679						1679	1679			1679			
		Upper Chester R	2390						2390		2390	2390				

State	Estuary	Area	Classification (acres)			Pollution Sources (acres)								Upstream Sources		
			Prohibited	Conditional	Restricted	STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	STP	Ur runoff	Wildlife
MD	*Potomac R*	Whites Neck Cr	215						215							
		Schoolhouse Branch	130								130					
		Chaptico Bay	620							620	620	620				
		Breton Bay	975			975			975							
		Herring Cr	266			266			266				266			
		Locust Grove Cv	60							60	60					
		Neale Sound	232						232							
		Piney Pt STP	200			200										
		Charleston Cr	130								130	130				
		Cuckold Cr	60			60										
		St. Patricks Cr	214						214				214			
VA	*Potomac R*	Goldman Cr			22				22				22			
		Cabin Pt Cr			102				102				102			
		Gardner Cr			143								143			
		Upper Machodoc Cr			511	511					511		511			
		entrance Upper Machodoc Cr			145						145		145			
		Upper Mattox Cr			286						286		286			
		Presley Cr			66		66									
		Lower Machodoc Cr -East			41				41				41			
		Lower Machodoc Cr - West			62				62				62			
		Upper Coan R			181						181		181			
		Lower Coan R		507							507		507			
		Upper Hull Cr			138				138							
		Popes Cr			306				306		306		306			
		Monroe Cr			306	306					306		306			
		Lower Mattox Cr		724							724		724			
		Peirce Cr			112	112							112			
		Mid Nomini Cr		133					133							
		Cod Cr			31								31			
		Rosier Cr			194						194		194			
		Upper Nomini Cr			302	302			302							
		Bonum Cr			82								82			
		Jackson Cr			61								61			
		Mid Coan R			38						38		38			
		Hack Cr			96						96		96			
	Rappahannock R	Parrotts Cr			122			122					122			
		E Br Corrotoman R		89					89		89					
		Totuskey Cr			757	757					757		757			
		Lagrange Cr			352						352		352			
		W Br Corrotoman R			259				259		259		259			
		shoreline/Rappahannock			25	25										
		Carter Cr			477	477			477							
		Whiting Cr			135						135					
		Mill Cr			51				51				51			
		Rapp/below Urbanna			1046	1046		1046	1046		1046		1046			
		Sturgeon Cr			58						58		58			
		Paynes Cr			28				28							
		Upper E Br Corrotoman R			224				224							
		Bush Park Cr			60								60			
		Lancaster Cr			167						167		167			
		Farnham Cr			263						263		263			
		Windmill Pt			68	68										
		Broad Cr			79								79			
		Greenvale Cr			92				92				92			
	York R	Jones Cr			44								44			
		Skimino Cr			44				44				44			
		C.G. and Wormley Cr			2891	2891			2891		2891		2891			
		Indian Field Cr			65								65			
		Cedarbush Cr			50				50				50			
		Upper Timbernack			65				65		65					
		Lower Timbernack		74					74		74					
		York R Cliffs			403	403			403							
		Sarah Cr			329			329				329				
		Cheatham Annex			660	660							660			
		Aberdeen Cr			73				73				73			
		Carter Cr North			54	54			54		54		54			
		Taskinas Cr			14				14				14			
		Carter Cr			22	22			22				22			
		Perrin R			88								88			
		Hockley Cr			13								13			
		Queen Cr			200				200				200			
		Morris Bay		138				138	138							
		Propotank/Adams/Indian Crs			384				384							
		Fox Cr/Cowpen Neck			15								15			
		Ware Cr			67				67		67		67			

State	Estuary	Area	Classification (acres)			Pollution Sources (acres)							Upstream Sources		
			Prohibited	Conditional	Restricted	STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	STP	Ur runoff	Wildlife
	James R	Mulberry Island		10893									10893			
		Knotts Cr			90			90	90				90			
		Streeter			8					8						
		Lower Warwick R		931					931				931			
		Upper Warwick R			478	478			478				478			
		Eastern Branch			184			184								
		Upper Cont Nansemond R		1522		1522										
		Lower Cont Nansemond R			1915	1915										
		Upper Pagan R		631							631		631			
		Lower Pagan R			1091	1091					1091		1091			
		Kings Cr			18				18		18		18			
		Lower Chuckatuck Cr		192					192				192			
		Upper Chuckatuck Cr			560				560				560			
		Norfolk/Elizabeth Harbors	6571			6571		6571		6571	6571		6571			
		Deep Cr			892	892					892		892			
		Upper James R			16683	16683		16683					16683	16683	16683	16683
		Upper Nansemond		617		617		617	617				617			
		Bennett Cr			170				170				170			
		Willoughby Bank		232		232		232		232			232			
		James R			35567	35567				35567						
		Hampton Roads			25303	25303		25303		25303			25303			
		Lower Elizabeth R	695					695								
		Lafayette R	1839					1839								
VA	Chesapeake Bay	Little Cr			1235	1235		1235								
		Thorntons Cr			60	60					60					
		Ware R			283	283					283					
		Wilson Cr			94				94				94			
		Poquoson R			472				472		472					
		North R, Back Cr			44						44					
		Tangier Island			1098	1098			1098							
		Jacobus Cr			80	80										
		Nassawadox Cr			78	78										
		Monday Cr			282			282	282				282			
		Back Cr			230			230	230							
		Chisman Cr			405				405							
		Onancock Cr		1856									1856			
		Chesconessex			41				41							
		Hunting & Deep Crs			285	285							285			
		Bagwell Cr			51			51			51	51	51			
		Pocomoke Sound			1499	1499		1499					1499			
		Starling Cr			48								48			
		Little Cr			537			537		537			537			
		Lake Rudee			99					99			99			
		E Br Lynnhaven R			714					714			714			
		Lynnhaven Bay		1364						1364			1364			
		Linkhorn Bay			836					836			836			
		Broad Bay		715						715			715			
		W Br Lynnhaven R			591	591										
		Pleasure House Cr			204					204	204					
		Long Cr			262					262			262			
		off Broad Bay I			30					30						
		off Broad Bay II			40	40										
		off Broad Bay III			38	38										
		Brick Kiln (closed)			209								209			
		Brick Kiln		96									96			
		Willoughby Bank		9955									9955	9955	9955	
		Hampton Roads			195	195		195		195			195			
		Cape Charles			306	306		306								
		Chesapeake Bay brdg/tunnel			19	19										
		Kings Cr			47								47			
		SW Br Back R		418					418		418		418			
		SW Br Back R			765				765		765		765			
		Harris R			235				235				235			
		Long & Grunland Crs			129				129				129			
		White House Cr			89				89							
		Davis Cr		43				43					43			
		Nassawadox Cr			95	95			95							
		Nandua			131			131				131	131			
		Pungoteague Cr			219	219					219		219			
		Taylor Cr			81						81					
		Gr Wicomico R, Balls Cr			59				59				59			
		Mill Cr			102						102					
		Indian Cr			247	247					247					
		Tabbs Cr			89			89			89		89			
		Dymer Cr			153						153		153			
		Narrows Pt			54	54					54		54			
		Stutts Cr			69				69		69					
		Queens Cr			90								90			
		Prentice Cr			8						8		8			
		Dividing Cr, Highland Ldg			20						20		20			
		Dividing Cr, Natty Pt Cv			8						8		8			
		Upper Dividing Cr			43						43		43			
		Harborton		53							53		53			
		East R/Put-In Cr			132	132			132		132					
		Poquoson R, Lambs Cr			105				105							
		Great Wicomico R		130		130							130			
		Willoughby bank		1196		1196		1196		1196			1196			
		Jackson Cr		200									200			
		Piankatank R		224					224							
		Cockrell Cr			875	875							875			
		Great Wicomico R			319	319							319			
		Upper Piankatank R			1068	1068			1068			1068				
		Onancock Cr			20	20		20					20			
		Healy Cr			38								38			
		Horn Harbor			84								84			

State	Estuary	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Urban/ Rural	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur runoff	Wildlife
	Total Chesapeake Bay		**65436**	**32933**	**111667**	**122603**	**66**	**61082**	**34820**	**89167**	**36877**	**25814**	**112829**	**26638**	**35670**	**16683**
	Percent of total					**58**	**<1**	**29**	**17**	**42**	**18**	**12**	**54**	**13**	**17**	**8**
	Total Potomac River		*3102*	*1364*	*3225*	*2732*	*66*		*3008*	*680*	*4234*	*750*	*4430*			
	Percent of total					*36*	*1*		*39*	*9*	*55*	*10*	*58*			
	Total Rappahanock River		*0*	*89*	*4283*	*2373*		*1168*	*2286*	*0*	*3126*	*0*	*3306*			
	Percent of total					*55*		*27*	*52*	*0*	*72*	*0*	*76*			
	Total York River		*0*	*212*	*5481*	*4030*		*467*	*4479*	*0*	*3151*	*329*	*4300*			
	Percent of total					*71*		*8*	*79*	*0*	*55*	*6*	*76*			
	Total James River		*9105*	*15018*	*82959*	*90871*		*52214*	*3056*	*87681*	*9203*		*85352*	*16683*	*16683*	*16683*
	Percent of total					*85*		*49*	*3*	*83*	*9*		*81*	*16*	*16*	*16*
MD	Chincoteague	Johnson Bay @ Taylor Land.	120					120								
VA		Mosquito Cr	102			102							102			
		Swans Gut Cr	78						78		78					
		Chincoteague Channel	415			415		415					415			
		Greenbackville	9										9			
	Total Chincoteague Bay		**724**			**517**		**535**	**78**		**78**		**526**			
	Percent of total					**71**		**74**	**11**		**11**		**73**			
	Total Mid-Atlantic	**Subregion**	**140427**	**55979**	**112634**	**161402**	**66**	**64830**	**52755**	**130527**	**53573**	**72262**	**144974**	**36032**	**41532**	**22624**
	Percent of total					**52**	**<1**	**21**	**17**	**42**	**17**	**23**	**47**	**12**	**13**	**7**

State	Estuary		Classification (acres) Prohibited	Conditional Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Ur runoff	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur	Wildlife
NC	Albemarle Sound	Kitty Hawk/Buzzard Bays	7426					7426				7426			
		Manns Harbor	5									5			
		Croatan Sound	235								235				
		Alligator R	30335								30335				
		Scuppernong R	9425					9425				9425			
		Callaghan/Spencer Crs	306								306				
		Perquimans R	3703							3703					
		Little R	7629							7629					
		Big Flatty Cr	663							663					
		Yeopim R	1999							1999					
		Pasquotank R	22945		22945					22945					
		Alligator R-inset	357								357				
		Alligator R	1471								1471				
		Northern Currituck Sound	45411								45411				
		Southern Currituck Sound	29089								29089				
		Shallowbag Bay	952		952							952			
		Ballast Pt	184									184			
		Engagement Hill	10		10										
		Albemarle Sound	73340		73340		73340			73340					
		Albemarle Sound	5926							5926					
		North R	12262							12262					
	Total Albemarle Sound		**253703**		**97247**		**73340**	**16851**		**129487**	**107214**	**17992**			
	Percent of total				**38**		**29**	**7**		**51**	**42**	**7**			
NC	Pamlico Sound	Cedar Bush Bay	255						255			255			
		Bay R	561		561		561	561							
		Gale Cr	153									153			
		Bear Cr	30					30							
		Stumpy Pt Bay	745						745		745				
		Middletown Cr		77						77					
		Wysocking Bay	163					163		163					
		North Bluff Pt	214							214					
		Oyster Cr	20	254								20			
		Swanquarter Bay	51		51						51				
		Rose Bay	82		82										
		Wills Cr	57				57					57			
		Baum Cr	163						163			163			
		Wanchese		408			408					408			
		White Pt	3									3			
		Atlantic Marina	1								1	1			
		Atlantic Boatyard	1								1	1			
		Steep Pt Marina	2									2			
		Pamlico/ferry landing	8									8			
		Jarrett Bay		2373						2373					
		Wade Cr		23						23					
		Williston Cr		44						44					
		Smyrna Cr	51							51					
		Avon	2									2			
		Salvo	2									2			
		Bay R inset	1612		1612			1612			1612				
		Far Cr	697					697				697			
		Silver Lake	41									41			
		ferry landing/Hatteras	31									31			
		Sandy Bay	133						133			133			
		Middens Cr		52						52					
		Broad Cr	20								20				
		Rodanthe	2									2			
		Salters Cr	192								192				
		Small and Nelson Crs	21									21			
NC	Pamlico & Pungo Rs	Bailey, Rose & North Crs	800								800				
		ICW from Goose Cr	22		22		22					22			
		South Cr	3639							3639					
		Pamlico R	38141							38141					
		ICW to Jones Bay	10		10		10					10			
		Satterthwaite/Wright Cr	317					317				317			
		Pungo R	17728		17728			17728	17728	17728					
NC	Neuse R	Clubfoot & Mitchell Crs	842					842		842					
		Neuse R	23648		23648				23648						
		Dawson Cr	390					390							
		Harlowe Canal	95					95							
		Upper Neuse R	7903		7903				7903						
		Adams Cr Canal & Back Cr	775							775					
		Smith, Kershaw and Greens Crs	865				865					865			
		South R	1122	2288						3410					
	Total Pamlico Sound		**101610**	**5519**	**51617**		**1923**	**22435**	**50575**	**67944**	**3422**	**3214**			
	Percent of total				**48**		**2**	**21**	**47**	**63**	**3**	**3**			
	Total Pamlico/Pungo		*60657*		*17760*		*32*	*18045*	*17728*	*59825*	*800*	*349*			
	Percent of total				*29*		*<1*	*30*	*29*	*99*	*1*	*1*			
	Total Neuse R		*35840*	*2288*	*31551*		*865*	*1327*	*31551*	*5122*		*865*			
	Percent of total				*83*		*2*	*3*	*83*	*14*		*2*			

State	Estuary		Classification (acres)			Pollution Sources (acres)							Upstream Sources		
			Prohibited	Conditional Restricted		STP	Direct Dischg	Industry	Septics	Ur runoff	Ag runoff	Wildlife	Boating	STP	Ur	Wildlife
	Bogue Sound	Harkers Island Marina	10										10			
		Harkers I	15									15	15			
		Queens Cr	219								219					
		off Queens Cr	28								28					
		Hunting Island	31			31										
		Goose Cr	68										68			
		Broad Cr	61						61							
		Broad Cr Marina	2										2			
		Jumping Run	31						31							
		Jumping Cr Marina	5										5			
		Bogue Sound Marina	2										2			
		Salter Path	136					136	136							
		Swansboro	1316	190		1506				1506			1506			
		White Oak R	1256	6432						7688						
		Starkey Cr	20						20							
		Pettiford Cr	92						92							
		Dudley Island Marina	2										2			
		North R	316	10200							10516					
		Morehead city	1071										1071			
		Calico Cr	1000			1000							1000			
		Shackleford Channel	37							37						
		Bear Cr	146									146				
		Gallant Pt	286					286		286			286			
		Davis Bay	797	280		1077		1077					1077			
		Spooners Cr	71										71			
		Pine Knoll Shores	22							22			22			
		Pelletier Cr	122							122			122			
		Atlantic Bch	52							52						
		Money Island Bay	60						60				60			
		Harlowe Cr	63	100									163			
		Newport R	970	7169					970	7169	8139					
		Core Cr		377									377			
		Shackelfoot Channel		665						665						
		Money Island Marina	2										2			
	Total Bogue Sound		**8369**	**25413**		**3614**		**1498**	**1370**	**17547**	**18902**	**161**	**5861**			
	Percent of total					**11**		**4**	**4**	**52**	**56**	**<1**	**17**			
NC	New R	Stones Cr	94			94										
		Everett Cr	99								99					
		Futiard Cr	120						120	120			120			
		Stones Bay outfall	138			138										
		Fannie Cr	138						138	138						
		Stones Bay		5410						5410						
		Alligator & Chadwick Bays	56	1680						1680	56					
		Ellis Cove		1521						1521						
		ICW/onslow Bch	68										68			
		Wilkins bluff	54			54							54			
		Trapps Bay		2213						2213						
		Biglins Cr	38						38	38			38			
		Upper Bay		2588						2588						
		Farnell & Morgan Bays	8178			8178			8178							
		Frenchs Cr	439			439										
	Total New River		**9422**	**13412**		**8903**			**8474**	**13708**	**155**		**288**			
	Percent of total					**39**			**37**	**60**	**1**		**1**			
NC	Cape Fear R	Cape Fear R	13301			13301				13301			13301			
		Cape Fear R	4367	9387		13754		13754		13754			13754			
		Snows Cut	49							49			49			
	Total Cape Fear River		**17717**	**9387**		**27055**		**13754**		**27104**			**27104**			
	Percent of total					**100**		**51**		**100**			**100**			
SC	Winyah Bay	Mud Bay		100								100				100
		Winyah Bay	16190					16190								16190
		Sampit R	2530			2530		2530		2530						2530
		Clambank Cr		192						192		192				
	Total Winyah Bay		**18720**	**292**		**2530**		**18720**		**2722**		**292**				**18820**
	Percent of total					**13**		**98**		**14**		**2**				**98**
	North and South Santee Rivers		**3927**									**3927**				
	Percent of total											**100**				
	Charleston Harbor	Folly R Marina	31										31			
		Charleston Harbor	17876			17876				17876						
		Upper Wando R	1102						1102							
		Wando R		5059		5059				5059						
	Total Charleston Harbor		**19009**	**5059**		**22935**			**1102**	**22935**			**31**			
	Percent of total					**95**			**5**	**95**			**>1**			

State	Estuary		Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	Direct Dischg	Industry	Septics	Ur runoff	Ag runoff	Wildlife	Boating	Upstream Sources STP	Ur	Wildlife
	St. Helena Sound	Fripp Island Canal	26						26				26			
		Fishing Cr	128							128		128				
		Big Bay Cr	73										73			73
		Lucy Pt Cr	343								343					
	sc87	Old House Cr	32			32							32			
	Total St. Helena Sound		**602**			**32**			**26**	**128**	**343**	**128**	**131**			**73**
	Percent of total					**5**			**4**	**21**	**57**	**21**	**22**			**12**
	Broad R	Broad R STP	163			163										
		Middle Cr	115			115										
		Battery Cr	451			451										
		Beaufort R	6361			6361										
		McCalleys Cr	426			426										
		Huspa Cr		425						425	425					
	87	Lawton Canal		43		43										
		Shelter Cove	50			50							50			
		Mackay Cr	25										25			
		Skull Cr	173										173			
		Laurel Bay	84			84										
		Hog Isl	47										47			
		Palmetto Bay	40			40							40			
		Long Cove	31			31							31			
		Baynard Cv Cr	110										110			
		Braddock Cove	35										35			
		Broad Cr	91										91			
		Calibogie Cay	64			64							64			
		Calibogie Shoal		28									28			
		Harbor Town	89			89							89			
		Whale Branch	488					488								
	Total Broad River		**8844**	**496**		**7917**		**488**		**425**	**425**		**784**			
	Percent of total					**85**		**5**		**5**	**5**		**8**			
SC	Savannah R		10139			10139		10139		10139						
	Jetty Area		27			27				27						
GA	Tybee Knoll Spit		2110											2110	2110	
	Total Savannah Sound		**12276**			**10166**		**10139**		**10166**				**2110**	**2110**	
	Percent of total					**83**		**83**		**83**				**17**	**17**	
	Ossabaw Sound	Adams Cr			458	458			458	458						
		Bradley R			14010											14010
	Total Ossabaw Sound				**14467**	**458**			**458**	**458**						**14010**
	Percent of total					**3**			**3**	**3**						**97**
	St. Catherines/ Sapelo Sounds	Upper Julleton R			678				678			678				
		Upper Johnson Cr			644							644				
		Cattle Pen Cr			1187							1187				
		Vandyke, Cedar, Ashley Crs			8823							8823	8823			
		Ossabaw Slough			407							407				
		West Ossabaw Island			6043							6043				
		Ossabaw Island Marsh			220							220				
		Cabretta Island			2093							2093				
		Blackbeard Cr			1958							1958				
		Rockdedundy Island			8018							8018				8018
		Doboy & Commodore Islands	864				864									864
		Doboy Sound			6950										6950	6950
	Total St. Catherines/ Sapelo Sounds		**864**		**37020**		**864**		**678**			**30071**	**8823**		**6950**	**15832**
	Percent of total						**2**		**2**			**79**	**23**		**18**	**42**
	Altamaha River				**2526**											**2526**
	Percent of total															**100**
	St. Andrew/St. Simons Sounds	Brunswick R	23468					23468								
		Upper Mackay R			398	398				398			398			398
		Hampton R			1458				1458							1458
		Stafford Island			500							500				
		Satilla R			3577							3577			3577	3577
		Jekyll Cr	1517			1577										
		Jekyll Sound	3653			3653						3653				
		Little Cumberland Island	2712									2712				
	Total St. Andrew/St. Simons Sounds		**31350**		**5933**	**5230**		**23468**	**1458**	**398**		**10442**	**398**		**3577**	**5433**
	Percent of total					**14**		**63**	**4**	**1**		**28**	**1**		**10**	**15**
FL	Indian River	Vero Beach & Fort Pierce	9230			9230			9230	9230						
		Bonaventure	877	4233					5110	4233			5110			
		Malabar	224	10690					10914			10914				
		Hutchins I	11822			11822			11822							
		Turnbull. Cr	541									541				
		Railway Bridge	969							969						
		Sebastion	2408	5049					2408			5049				
	Total Indian River		**26071**	**19972**		**21052**			**39484**	**14432**		**16504**	**5110**			
	Percent of total					**46**			**86**	**31**		**36**	**11**			
	Total Southeast Subregion		**512424**	**79550**	**59945**	**258756**	**864**	**143331**	**92336**	**160598**	**216256**	**172161**	**69728**	**2110**	**12637**	**56694**
	Percent of total					**44**	**<1**	**24**	**16**	**27**	**37**	**29**	**12**	**<1**	**2**	**10**

Glossary

Approved Waters	Waters from which shellfish may be harvested for direct marketing.
Closure Area	An area in which limitations are placed on shellfish harvest.
Coliform Bacteria	A group of bacteria present in sewage that are used to indicate possible presence of enteric pathogens of sewage origin. Fecal coliform bacteria are a subset of the total coliform bacteria group and more specifically indicate presence of fecal material.
Conditionally Approved Waters	Waters that meet approved classification standards under predictable conditions. These waters are opened to harvest when conditions are met and are closed at all other times.
Depuration	A controlled purification process in which shellfish from restricted areas are placed in tanks containing bacteria-free water usually for 48 hours before marketing.
Enteric pathogens	Human intestinal bacteria or viruses that cause gastroenteritis or hepatitis.
Harvest-limited	Waters that are classified as prohibited, conditionally approved, or restricted.
National Shellfish Sanitation Program	A cooperative program of the U.S. Food and Drug Administration, shellfish-producing states, and the shellfish industry to control harvest and distribution of molluscan shellfish for human consumption.
Prohibited Waters	Waters from which shellfish may not be harvested for direct marketing. Until 1986, relaying was allowed in prohibited waters.
Relay	The transfer of shellfish from restricted (or prohibited until 1986) waters to approved waters for natural cleansing using the ambient environment as a treatment system.
Restricted Waters	Waters from which harvest may occur only if shellfish are relayed or depurated before direct marketing.
Sanitary Survey	The evaluation of all factors determining the classification of waters, including actual and potential pollution sources, hydrographic and meterorologic conitions, and coliform bacteria sampling results.
Shellfish	Edible species of oysters, clams, and mussels.
Shellfishing Waters	Waters that are classified for the commercial harvest of shellfish for human consumption under the National Shellfish Sanitation Program.